ELECTRICAL PRACTICE IN COLLIERIES.

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ELECTRICAL PRACTICE

IN

COLLIERIES.

A Manual

FOR COLLIERY MANAGERS, UNDER-MANAGERS, ENGINEERS, AND MINING STUDENTS.

BY

DANIEL BURNS, M.INST.M.E.,

CERTIFICATED COLLIERY MANAGER; LECTURER ON MINING AND GEOLOGY, THE GLASGOW AND WEST OF SCOTLAND TECHNICAL COLLEGE.

With 142 Illustrations and Numerous Examples of the Calculations Involved.

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PREFACE.

DURING recent years the application of electric power in and about collieries has been extending rapidly, and at present few collieries of importance are without installations for the generation of electricity.

This little book is written with the intention of giving a short description of a few of the principal applications of this form of energy about collieries, and to serve as a guide to students who may be preparing for Certificates as Mine Managers, and who will, as time advances, be called upon to deal with questions and methods such as are here dealt with.

The ever-increasing demand for electric power in mines should form a sufficient reason for this attempt to put some information of a practical nature before that section of the public whose interests are largely bound up with recent developments and improvements in coal-working machinery. No attempt has been made to deal with the purely scientific aspects of the subject, but merely to include such technical details that the author has found to be of service in his own practice, and which, he hopes, will be of some service to Mining Students, Colliery Managers, and other responsible officials who may have to deal with the electrical equipment of collieries.

Arithmetical examples have been included at the end of several of the Chapters for the benefit of those students who may peruse the book. The answers given to these examples are only correct to the nearest round number, having in most cases been obtained by the use of the slide rule. If any errors come under the observation of those using the book, the author would feel much obliged if they would point them out to him..

The author gratefully acknowledges his indebtedness to many of the Technical Journals for information included in the book, and has also to thank the General Electric Company, Messrs. Ernest Scott & Mountain, the British Thomson-Houston Company, Messrs. Mavor & Coulson, and the Grant Electric Drill Company for the loan of process blocks, and the Jeffrey and other Companies who supplied photographs of their manufactures.

He has also further to express his thanks to the publishers for the pains that have been taken both with the text and the illustrations.

D. B.

Glasgow, January, 1903.

CONTENTS.

ELECTRICAL PRACTICE IN COLLIERIES.

CHAPTER I.

UNITS OF MEASUREMENT, CONDUCTORS, &c.

Before attempting to ascertain the mass or volume of any object, periods of time, &c., it is necessary to select some definite unit, in terms of which the quantities under examination may be expressed. In other words, we must adopt some standard, by comparison with which we may seek to determine the mass or volume of a body, a period of time, &c. Thus when we speak of 5 lbs., or 5 tons, we mean five times the quantity of matter contained in a well-defined unit known as a *pound* or a *ton*. Obviously the unit employed must be one referring to quantities of the same order as those we are seeking to ascertain—*i.e.*, a unit of weight to express quantities of matter under gravitational influences, or one of volume to express size or bulk. The units selected may be, and indeed in practice often are, quite arbitrary, but as long as they convey definite conceptions, constant under all conditions, they will serve their purposes as standards of comparison. The term pound is such a conception,* a pound of white-hot iron or of ice-cold water being, in either case, definite and invariable quantities of matter. Prior, therefore, to discussing the applications of electricity to mining operations, it will be well to consider the units employed to express those properties of electricity upon the development of which its operations depend.

* The pound referred to above is to be regarded as a unit of mass, and as such is invariable under all circumstances. Regarded as a unit of weight—*i.e.*, mass under gravitational attraction—it will vary at different points or levels on the earth's surface; even under these conditions its value as a unit remains unimpaired, inasmuch as the other quantities of matter with which it is compared will be affected similarly to itself, their relative weights being unaltered.

Electrical currents are measured by the effects they produce, the units employed being the expression of the effects produced in unit periods of time, under unit conditions. The units are as follows :—

The Volt.—This is the unit of potential or pressure, and expresses the difference existing between two or more currents of electricity, this pressure being regarded as the tendency of an electrical current having a high potential to flow toward areas in which the potential is lower. The volt is determined by the difference in potential between the two poles of a specially-constructed cell known as Clark's, under special conditions of temperature (15° C. ; 59° F.), this difference being, according to the official definition propounded by the Board of Trade, equal to 1·434 volts. **E.M.F.** (*Electromotive force*) is an old term frequently confused with voltage, but it expresses, not the difference in potential itself, but the force *due* to this difference. The unit is, however, the same.

In practice the pressure of the current is measured by an instrument called a voltmeter, graded from a standard instrument expressing legal units.

When a current of electricity flows from one point to another a certain amount of potential is dissipated in overcoming the resistance of the conductor over which it passes, hence we have a fall in pressure taking place all along the path that the current traverses. The higher pressure is spoken of as being positive or + , the lower as being negative or – .

Electrical pressure can be generated by various methods, but the motion of a conductor in a magnetic field is the method in practical use for generating power. This will be described later.

Ohm.—As already stated, a conductor offers resistance to the flow of an electric current. The unit in use for measuring this resistance is called the *ohm*, and is the resistance offered by a column of mercury, the cross sectional area and length of which are constants. At 32° F., 0° C., the column has a mass of 14·452 grammes, a length of 106·3 centimetres, and a uniform diameter. The standard instrument of the Board of Trade offers a resistance of 1 ohm to the passage of an unvarying current when the temperature of the coil of wire, which in this instrument is substituted for the column of mercury, is 85·4° C. Measuring instruments called ohmmeters are used for the purpose of determining the resistance of a circuit.

The resistance of a copper wire $\frac{1}{16}$ of an inch diameter and 130 yards long is approximately equal to 1 ohm.

Ampere.—This term expresses the quantity of current flowing

along a conductor, and may be compared to the quantity of water flowing through a pipe, or the amount of air passing through an airway. The ampere is defined as the unvarying current which, when passed through a solution of nitrate of silver (under certain specified conditions), will deposit silver at the rate of 0·001118 of a gramme per second. It is the current which is passing through the coils of the Board of Trade Standard Instrument; when on reversing the current in the fixed coils, the change in the forces acting upon the suspended coil in its sighted position, is exactly balanced by the force of gravity upon a certain platinum weight.

Instruments graded from the above standard, and known as ammeters, are used for making practical measurements of the quantity of current.

Ohms Law.—This expresses the relationship between the units of quantity, pressure, and resistance, and may be summarised as follows:—

Let C = current in amperes.
,, E = pressure of current in volts.
,, R = resistance in ohms.

Then $C = \frac{E}{R}$ (1), $E = C \times R$ (2), and $R = \frac{E}{C}$ (3).

The following examples may serve to illustrate the use of the foregoing formulæ:—

Find the pressure required to send a current of 20 amperes through a resistance of 10 ohms.

$$E = C \times R = 20 \times 10 = 200 \text{ volts.}$$

A current of 40 amperes is passing through a circuit at a pressure of 180 volts. Find the resistance of the circuit.

$$R = \frac{E}{C} = \frac{180}{40} = 4{\cdot}5 \text{ ohms.}$$

Watt.—This is the unit of work performed by the current, and is equivalent to foot-pounds in mechanics. It is obtained by multiplying 1 volt by 1 ampere, and is consequently often termed the volt ampere; 746 such units are equal to one horse-power.

In practice installations are always fitted with an ammeter, and voltmeter, and as a consequence, it becomes an easy matter to obtain the horse-power being expended, or otherwise the rate at which work is being done. Take the following as an example:—

A dynamo supplies current to drive a pump, the pressure is 210 volts, and the quantity 50 amperes. Find the electrical horse-power—

$$\text{H.P.} = \frac{\text{volts} \times \text{amperes}}{746} = \frac{210 \times 50}{746} = 14{\cdot}08 \text{ nearly.}$$

The *watt* is a comparatively small unit, and it has become customary to express the output of large machines in **kilowatts** (1000 watts).

For convenience it may be stated that 1 watt is equal to about $44\frac{1}{4}$ foot-pounds, and as 746 watts are equal to 1 horse-power, the kilowatt is equal to about $1\frac{1}{3}$ horse-power (1·34).

For other units which are of less importance to the practical engineer, such as the Coulomb, the Farad, the Henry, the Joule, &c., the reader may be referred to works of a more technical nature.

When a difference of electrical pressure has been set up it is necessary to provide a path for the current to traverse. Such a path must be continuous between the regions of high and low pressure, and must be capable of carrying current; or, in other words, must be formed by some conducting material, usually copper wire, while the distance traversed from the point of generation and back again is called the circuit.

Circuits may be divided into two classes called series, and shunt or parallel. The arrangement of the series circuit is shown in Fig. 1, where one continuous path is opened for the

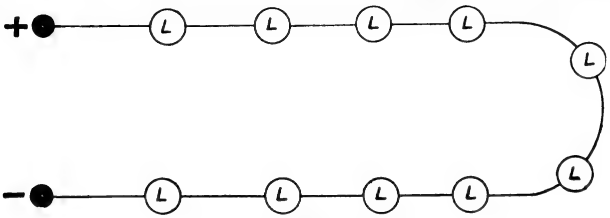


Fig. 1.—Series Circuit.

current which flows from the point of high to that of low pressure or potential. Lamps, motors, &c., are inserted at points along the path, and the current performs work in overcoming their resistance.

In the shunt or parallel system two mains or leads are used, their connections are made to the points of high and low pressure, and cross connections made between them, at points where a lamp, motor, &c., may be wanted. The arrangement is shown

by Fig. 2. The current flowing along the mains divides itself among the various branches or cross connections thus made, in inverse proportion to their resistance.

A little consideration will show that in the series circuit the total resistance equals the sum of the separate resistances placed in the path of the current, because they form a continuous path, and the strength of the current flowing will be the same all along that path. In the case of the parallel circuit the total resistance is less than any of the branches, and as the branches bridge across the two mains the sum of their cross sections may be taken as equal to one wire whose cross section is equal to that of the main.

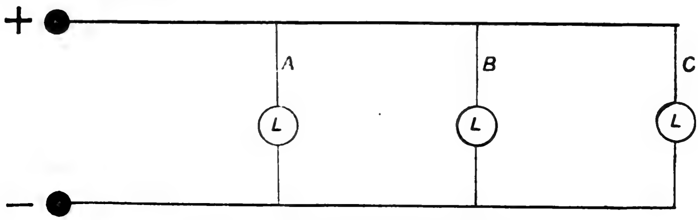


Fig. 2.—Parallel or Shunt Circuit.

The resistance of the circuits, A, B, and C, in Fig. 2 may be taken as 20, 30, and 40 ohms, and the total current flowing as 91 amperes, if r_1 be resistance of A, r_2 resistance of B, and r_3 resistance of C; then the current in A will be to the whole current as $\frac{1}{r_1}$ to $\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}$, that is

$$\frac{\text{Current in A}}{\text{Total current}} = \frac{\frac{1}{r_1}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}},$$

$$\frac{\text{Current in A}}{91} = \frac{\frac{1}{20}}{\frac{1}{20} + \frac{1}{30} + \frac{1}{40}},$$

$$\therefore \text{ Current in A} = 42 \text{ amperes.}$$

Again,

$$\frac{\text{Current in B}}{\text{Total current}} = \frac{\frac{1}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}},$$

$$\frac{\text{Current in B}}{91} = \frac{\frac{1}{30}}{\frac{1}{20} + \frac{1}{30} + \frac{1}{40}},$$

$\therefore$ Current in B = 28 amperes.

Again,
$$\frac{\text{Current in C}}{\text{Total current}} = \frac{\frac{1}{r_3}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}},$$

$$\frac{\text{Current in C}}{91} = \frac{\frac{1}{40}}{\frac{1}{20} + \frac{1}{30} + \frac{1}{40}},$$

$\therefore$ Current in C = 21 amperes.

The same method of calculation would apply for any number of parallel branches.

In the foregoing example, three resistances in parallel in the same circuit have been given, namely, 20, 30, and 40 ohms, and from these known quantities, the total resistance of the circuit can be calculated. Since the reciprocal of the joint resistance is the sum of the reciprocals of the separate resistances, if the same notation be used as before, but with R as the total resistance. Then

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}$$
$$= \frac{1}{20} + \frac{1}{30} + \frac{1}{40}$$
$$= \frac{13}{120};$$
$$\therefore\ 13\,R = 120,$$
$$R = 9{\cdot}23 \text{ ohms.}$$

When a continuous path is formed for the current to traverse, the circuit is said to be closed. When a gap or discontinuity is formed in the path in such a manner as to prevent the flow of current, the circuit is said to be open. Should some material which is a conductor, and which offers less than the normal working resistance, bridge across the circuit, the current will flow along the path thus opened, and what is termed a short circuit is formed.

Since the colliery engineer is often called on to fix up circuits about a colliery, it may be of some service to give particulars of the safe carrying capacity of electrical conductors in ordinary use. The current is taken as 1000 amperes per square inch of section of the cable. It is usual to make such cables of a number of smaller wires twisted together, the size of cable is then expressed as a fraction, the numerator showing the number of wires in the cable, and the denominator showing the gauge of the wire.

Standard Gauge of Wire.	Weight per Mile in Lbs.	Resistance per Mile in Ohms.	Carrying Capacity in Amperes.
7/22	90	9·908	4·4
7/21	117	7·596	5·7
7/20	148	5·998	7·2
7/19	183	4·861	8·9
7/18	263	3·380	12·9
7/17	358	2·477	17·6
7/16	468	1·895	23·0
7/15	592	1·498	29·1
7/14	731	1·214	35·9
7/13	967	0·9179	47·5
7/12	1,235	0·7183	60·7
7/11	1,537	0·5776	75·5
7/10	1,870	0·4744	91·9
19/22	244	3·634	12·0
19/21	318	2·795	15·6
19/20	403	2·202	19·8
19/19	497	1·786	24·4
19/18	714	1·243	35·1
19/17	975	0·9103	47·9
19/16	1,272	0·6976	62·5
19/15	1,610	0·5512	79·1
19/14	1,987	0·4467	97·6
19/13	2,625	0·3380	129
19/12	3,358	0·2642	165
19/11	4,173	0·2126	205
19/10	5,090	0·1744	250
37/19	971	0·9140	47·7
37/18	1,396	0·6355	68·6
37/17	1,901	0·4667	93·4
37/16	2,483	0·3574	122
37/15	3,134	0·2831	154
37/14	3,887	0·2283	191
37/13	5,129	0·1730	252
37/12	6,554	0·1354	322
37/11	8,160	0·1087	401
37/10	9,931	0·0893	488
61/18	2,300	0·3859	113
61/17	3,134	0·2831	154
61/16	4,091	0·2169	201
61/15	5,189	0·1710	255
61/14	6,410	0·1384	315
61/13	8,467	0·1048	416
61/12	10,820	0·0819	532
61/11	13,450	0·0659	661
61/10	16,390	0·0541	805

When current is transmitted through a cable, work is done in overcoming the resistance of the cable, and a fall of voltage takes place. This fall of voltage may be found by multiplying

the resistance of the cable by the current flowing. It is necessary to remember that the distance between the dynamo and motor must be doubled in making this calculation, as both outgoing and return conductors have to be taken into consideration.

Example.—Find the loss of volts in a 7/14 cable when the total length is one mile and the current flowing 35 amperes.

From the table a 7/14 cable has a resistance of 1·214 ohms per mile,

$$\therefore \quad 1{\cdot}214 \times 35 = 42{\cdot}49 \text{ volts lost.}$$

An approximate rule (accurate enough for ordinary practice) is that, where the current density is 1000 amperes per square-inch section of copper, the loss is 2½ volts per 100 yards of cable.

When estimating the size of dynamo to drive a motor, or do other work, the loss due to transmission along the cables must be taken into account, and the dynamo constructed to give an E.M.F. at its terminals equal to that required by the motor, plus that lost in transmission.

The work lost in watts in a cable may be found by squaring the current (in amperes) and multiplying by the resistance.

Example.—Find the watts lost in a 7/14 cable when carrying a current of 35 amperes.

$$35 \times 35 \times 1{\cdot}214 = 1487{\cdot}15 \text{ watts for each mile length of cable.}$$

The watts lost will vary with the length, increasing as the length increases, and decreasing as the length decreases. By suitable selection, the power used up in the cable can be made as small as desired. But unreasonable increase of size will increase the first cost of cable to such a point that no economy will result.

There are a great many classes of cables suitable for electrical power transmission. Where cables are used in such a position that they are out of reach of persons and can readily be insulated from earth, bare copper wire is commonly used; in the mine, however, it becomes necessary to use insulated cables. An insulator is a substance which offers a very high resistance to the passage of electricity, and which is, therefore, applied to the surface of a conductor to prevent leakage, as the tendency of the current is always to pass to earth if it can only find a suitable path. Insulation is usually measured in megohms, one megohm being equal to one million ohms; in practice, the insulation test is made by immersing the insulated cable for twenty-four hours in salt water, and then taking the insulation resistance between the conductor and the earth. The insulating materials used for the insulation of cables are—

(1) Indiarubber (pure),
(2) Vulcanised indiarubber,
(3) Vulcanised bitumen,
(4) Bitumenised fibre,
(5) Paper.

For colliery work bitumen is largely used, but should have additional protection by being armoured with galvanised iron wire or steel tape. When such cables are used underground, a

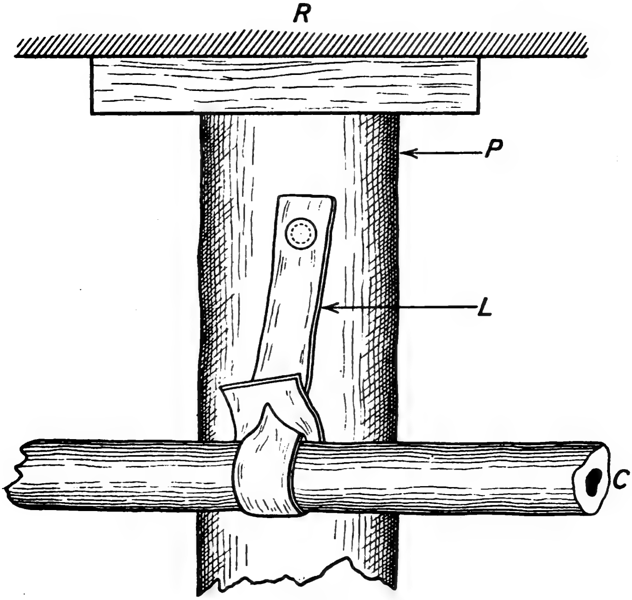


Fig. 3.

R = Roof.
P = Prop set up to roof.
L = Loop of leather.
C = Cable slung by leather loop.

good coating of Stockholm tar, applied at intervals, will greatly prolong their life. When cables are led underground, it is always advisable to have them, if possible, carried along the intake airways, as the return air has a more injurious effect upon the armouring. Such cables should not be fastened to the props by wooden cleats, as is often done, but should be suspended by loops of tarred cloth or leather (Fig. 3). Should a fall of roof take place, the supporting loops give way easily, and

the cable is carried to the ground, thus lessening the risk of its being broken or cut through.

A good class of vulcanised indiarubber braided cable is also much in use, and gives satisfactory results in many cases. Plain braided cables are also used, but this form requires ample space and total absence of moisture, a condition of things not usually met with in collieries. In colliery work, the chief requirements of cables are mechanical strength, efficient and durable insulation, with a certain amount of flexibility, their insulation resistance being from 300 to 5000 megohms per mile. For vulcanised rubber, the 3000 megohms grade wears well, and is perhaps better for rough colliery work than the higher grade insulation where the vulcanised rubber is softer and less likely to wear well on that account. A good plan is to make periodic tests of the insulation, not that this prevents leakage, but it ensures its discovery before things have gone far enough to be serious, and has the effect of keeping the system in good condition by enabling slight defects to be discovered and remedies applied at once when necessary.

Concentric cables with their outer conductors bare, or, in some cases, with outer conductors protected from corrosion by braiding and tarring, are also used, and these form a class of cables well suited for mining work. The inner cable being protected by the outer is placed beyond reach of accidental contact, while the outer being at earth potential can be handled without risk. Should the cable be damaged by a fall, the outer conductors would be pressed in upon the inner, thus forming a short circuit which would at once blow the fuse and put the whole system out of circuit. Thus, as far as the risk of shock to persons is concerned, this system affords the greatest security from danger.

In some cases single insulated cables are used and the earth itself employed as the return way. This practice cannot be too much condemned, as the whole mine forms the return circuit, and water-pipes, rails, &c., suffer from oxidation, due to this cause, especially if the mine be a damp one. There is also the danger of shock to persons if any part of the insulation of the wire carrying the current should break down and the wire be accidentally touched at that part, as the person touching the wire would have the greater portion of the current pass through his body on its way to earth, and, with a high voltage or in a wet part of the road, this might produce serious results.*

* Since writing these lines, the author has had brought under his notice a serious accident, resulting in the loss of a life, due to the use of a single cable with earth return. Men were employed repairing the road, the roof of which was supported by steel girders. During the operations one of the

Concentric cables insulated from each other and also upon the outside, and of which Fig. 4 shows a section, are also used; in many cases they are drawn inside a lead pipe to afford protection from damage. Another and a very good method of protecting cables underground is to lay them in semicircular wood channels; place these channels inside a wood box, and then run the whole full of pitch. This method is shown in Fig. 5, and answers well enough where the floor of the mine is even and not likely to be much disturbed. Pitch is not a high insulator, but it affords protection to the insulation upon the cables by keeping out damp, and also prevents mechanical injury in a very efficient manner.

Cables should never be exposed at any place where horses may have to stand while waiting for tubs, &c., as these animals have a habit of nibbling anything within their reach, and might easily bite through ordinary insulation if they had access to the cables.

Where steampipes exist in the mine great care should be taken to keep the cables as far removed from them as possible, as leakage of steam would soon cause a breakdown of the insulation. Runaway tubs are another source of danger to cables, and every precaution ought to be taken when laying them to prevent possible accident from this source.

Proper junction boxes should be used for all joints, and a switch of the single pole type fitted on each conductor where joints exist. These switches should be coupled on the outside, and completely lined with slate to prevent any possibility of an arc being started. With proper precautions and attention, the risk incurred during the conveyance of the current along the mine roadways may be reduced to a minimum, and with the pressures usually employed (under 500 volts) should seldom, if ever, be the cause of serious accidents.

In joining up cables to terminals, it should always be borne in mind that the outside braiding on ordinary cables is not by any means a good insulator, and should on that account be kept back from the "live metal."

Where such a joint has to be made the braiding should be stripped back for about 2 inches, and the exposed rubber

---

girders was taken out, and, in falling, had evidently dropped on the cable, at the same time damaging the insulation and baring a part of it—one end resting on this bare part. The deceased went forward and grasped the girder to draw it back, but received a severe shock and was unable to let go his hold. Although his fellow-workmen made an immediate attempt to get him off, he remained over a minute in contact and was dead when released.

painted over with some non-conducting preparation, such as shellac varnish.

Existing circumstances will largely determine the class of cable available, but where steel armouring is employed in shaft cables, to assist in carrying the weight of the cables, care should be taken to see that locked or wedged armouring is used, or two layers of steel wires spirally wound in opposite directions may be used with equally good results.

When bare cables run above ground high-pressure charges may be developed in them during a thunderstorm by a discharge of lightning into the system. Such a discharge would affect instruments or machinery upon the circuit, and to prevent damage from this source the line must be provided with a lightning arrester. These instruments are of various types, that known as the brush being very suitable for open lines about

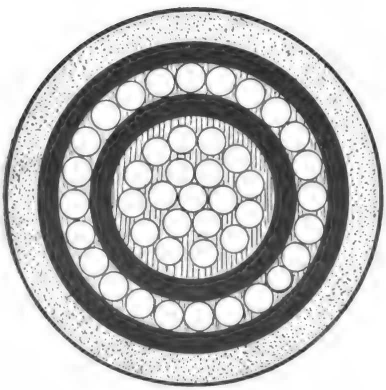


Fig. 4.—Section of Concentric Cable.

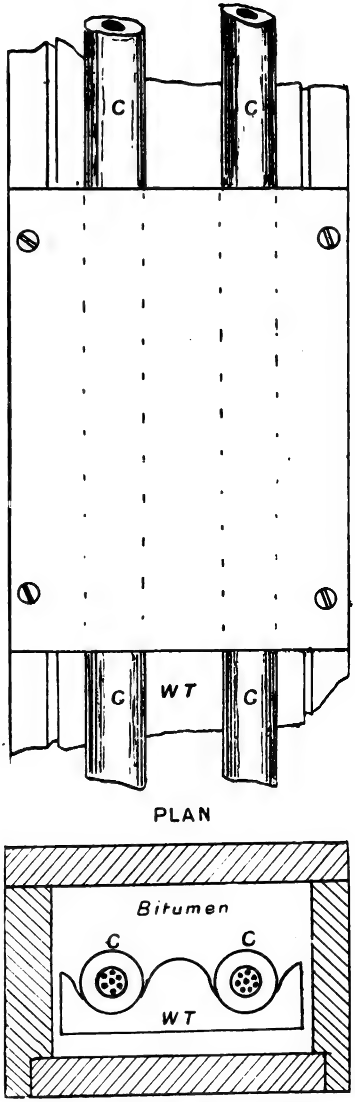


Fig. 5.—Wood Box for Carrying Cables.
W T = Grooved wood trough.
C C = Insulated cables.

collieries. Fig. 6 shows the construction of this appliance. The terminal T_1 is connected to one of the mains, the other terminal T_2 is connected to earth. The current flows through the solenoids S S, and from thence to a pivoted arm, A, which ends in a point, from there across a small gap to a carbon stud through the terminal T_2, and then to earth.

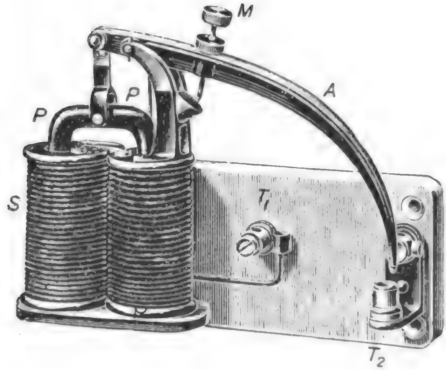


Fig. 6.—Lightning Arrester.

When a lightning discharge occurs it sparks across the gap. If the current in the main follows and sets up an arc across the gap, the current passing through the solenoids is strong enough to draw down the plungers, P P, and so break the arc, the arm falling back to its normal position by gravity. A set screw, M,

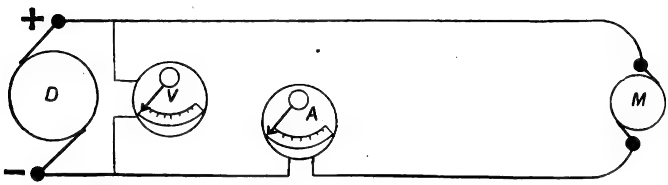


Fig. 7.—Method of Fixing Instruments on Circuit.

D = Dynamo. | V = Voltmeter connected in shunt.
M = Motor. | A = Ammeter connected in series.

is fitted so as to vary the width of gap at will. Arresters should be connected to each main.

In measuring the current the measuring instruments are usually fitted upon a slate base, which also carries the main switches connected with the installation, the arrangement of

switches will depend wholly on the number and conditions of the branch circuits to be fed, but the voltmeter and the ammeter will have to be connected up to the mains so as to obtain correct readings.

To effect this the instruments are arranged as shown in Fig. 7, the voltmeter being connected to a shunt bridging the two ends of the mains close to the dynamo, and thus obtaining the difference of pressure between the two ends of the circuit. The ammeter (Fig. 8) is connected in series to one of the mains so that the whole of the current generated passes through it, thus giving a reading of the amount of current flowing. Simultaneous readings of the two instruments will give the rate of expenditure of energy in the circuit, the product of the two being watts, as already explained.

The voltmeter (Fig. 9) is an instrument of extremely high resistance, and is connected up to the two points whose difference of potential has to be measured. Its resistance should be such that when connected to the circuit the total resistance of the circuit should not be decreased, to any appreciable extent, by the connection of the various cables. The instruments should all be mounted upon an enamelled slate or marble base. This base should where possible be fixed out from the wall a sufficient distance to allow easy access to the connections at the back. When a switchboard is set up underground, care should be taken to have it thoroughly insulated, and protected from the fine coal dust which is present in the atmosphere of most mines.

Too much stress cannot be laid upon keeping a switchboard free from coal dust as the fine particles form a fairly good conductor for the current, and may readily cause the formation of an arc between contacts or otherwise.

Another important instrument in addition to the ammeter and voltmeter is an ohmmeter arranged to give the insulation resistance between each pole and the earth direct. It should be fitted in all cases where the power has to be conveyed through long lengths of cable. Such an instrument is shown in Fig. 10.

With such an instrument, connected up as shown in Fig. 11, the direct reading of the insulation resistance of either main can be obtained according as the switch is turned to the positive or negative block.

A book can be kept and the insulation resistance noted from time to time, and entered up. This will secure the prompt detection of any leakage that may occur.

Should the demand for current fluctuate greatly, as in the case of a generating plant supplying current to several coal-

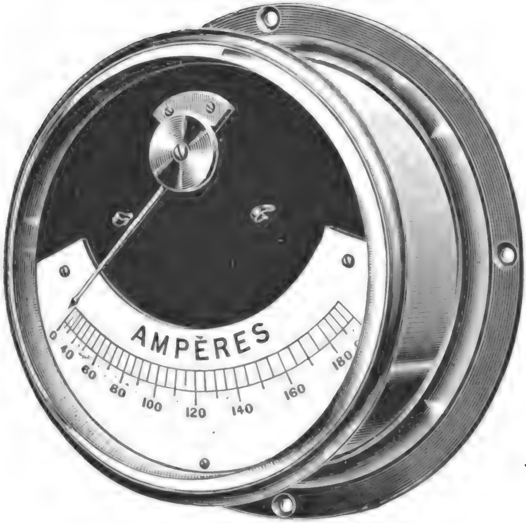


Fig. 8.—Ammeter.

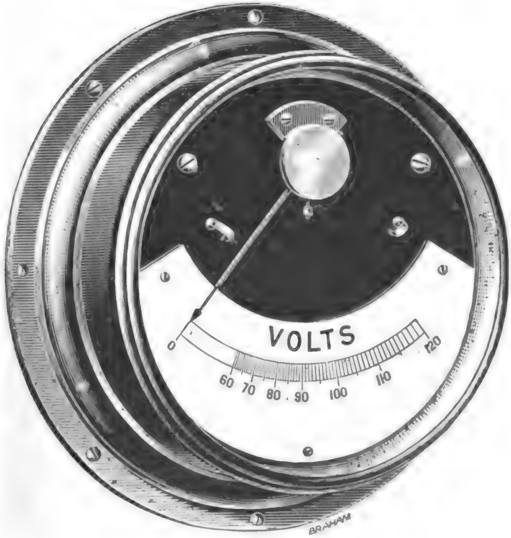


Fig. 9.—Stanley Voltmeter.

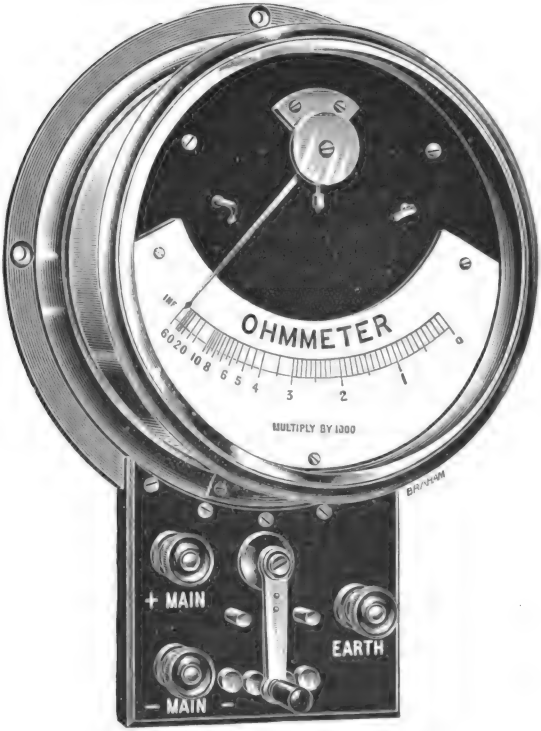


Fig. 10.—Ohmmeter for Switchboard.

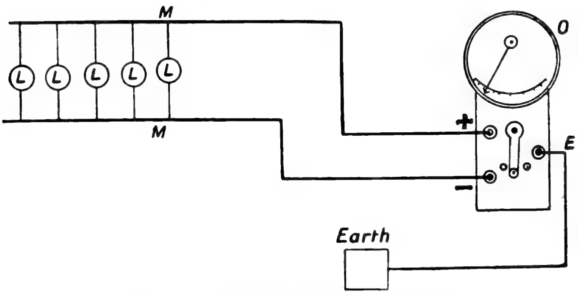


Fig. 11.—Connections of Ohmmeter.

O = Ohmmeter.	L = Lamps in parallel.
M M = Mains.	E = Earth wire.

cutting machines, then dead-beat voltmeters and ammeters would be the best instruments to use.

A very suitable instrument is that known as the Stanley D'Arsonval moving coil voltmeter or amperemeter, some of the advantages of which are as follows:—

1. Accuracy greater than can be obtained with electro-magnetic instruments.

2. Voltmeters are of very high resistance, absorb a very small amount of energy, and do not heat.

3. There is no hysteresis error either with voltmeters or ammeters—that is to say, the instrument will read the same with a given current or voltage whether that value is approached by rising or falling.

4. Both ammeters and voltmeters are dead beat.

5. Heavy leads need not be run up the back of the board to the ammeters as they do not carry the main current; the shunts can be connected in circuit where convenient and comparatively thin wires led to the instruments.

The Kelvin electrostatic instruments are also well suited for conditions such as obtain in mines, being extremely accurate and constant. It is not often, however, that colliery requirements render the use of such high-class instruments necessary.

The fixing of shaft cables is one of the most important points connected with the installation of a colliery, as the usual conditions existing in the shaft are not in favour of cables. In the first place, the shaft is likely to be more or less wet, and, in the second, there is the chance of damage being done by small pieces of coal falling off the tubs during winding. Further, should the shaft be an upcast one, the nature of the return air and the effects it will produce on certain classes of cables must be considered. Many different methods of overcoming these drawbacks have been adopted, and various classes of cables have been used with varying results. Some engineers recommend the use of wood casing all through the shaft, others the employment of lead-covered cables; both measures are costly, and the latter has the further drawback of possessing a pronounced tendency to creep. Cables covered over with pure rubber have also been used, but do not last any length of time, chiefly on account of the soft nature of the insulation. The cable most in use, and giving good results, is that insulated with vulcanised indiarubber, of not too high grade, and braided on top. The high grades of vulcanised rubber are rather soft for the purpose, and a good thickness of the medium grade, which is much harder, answers the purpose very well.

In some cases the rubber core is covered with a preservative

compound, wound with jute yarn and then sheathed with galvanised iron or steel wire, and finally coated with prepared jute. This class of cable is largely used, and gives good results, even in cases where a considerable amount of water is falling in the shaft.

The cables should always be placed as much out of the water and the way of anything falling as possible, and should be suspended from as few places as is consistent with the requirements of the case.

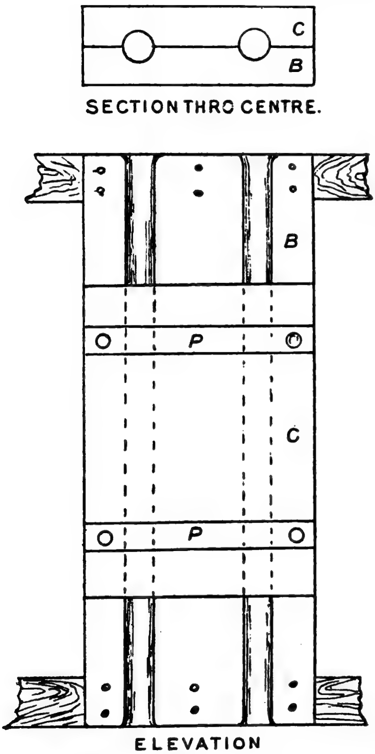


Fig. 12.—Shaft Cleat.

B = Wood block. | C = Wood cover.
P P = Insulated clamping plates.

One form of cleat for suspending shaft cables is shown in Fig. 12, where B is a block of red pine about 7 inches wide × 3 inches thick, and of a length equal to that between buntons; P P are two iron plates $\frac{3}{8}$ inch thick by $2\frac{1}{4}$ inches broad, which clamp down a cover, C, of red pine of the same width and thickness as B, but only 3 feet in length; the blocks are pierced by longitudinal grooves suitable for the size of cable to be employed. In fixing the cables the part underneath the clamp should be rolled with brattice cloth, or, better still, with old pieces of indiarubber hose, if such are to be had.

Shaft cables are sometimes run in iron piping, which is clamped to the brick or wood lining of the shaft. Where this is done, boxes are put in at intervals, each box containing a clamp which is used for suspending the cable. The boxes are fitted with a watertight lid which excludes all wet. Such a box is shown in Fig. 13, with the lid removed.

Another very neat and effective method of suspending the cables is adopted at Acton Hall, and is the design of Mr. Roslyn

Holiday, the engineer. The conductors used are 19/12 hard-drawn copper wire, braided on top so as to avoid shock by accidental contact, and are suspended from top to bottom. A beam, B (Fig. 14), projects into the shaft and supports a specially made insulator, I, by means of an eyebolt, which carries an iron clamp by which the cables are supported. The cables being only braided renders the use of an insulator compulsory.

The conditions are favourable for this particular method, as there is ample clearance in the shaft and no water to speak of. Mr. Holiday states that the method has given every satisfaction

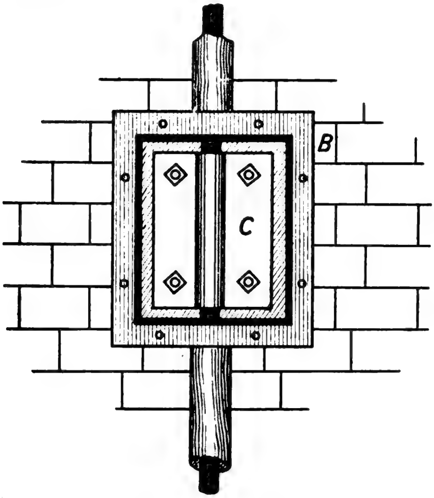


Fig. 13.—Support Box.

B = Box. | C = Cable clamp.

since its adoption, but, as a safeguard, the cables are tested for leakage each week end.

Any of the methods of suspension described above are quite suitable for use with concentric cables as well as with ordinary ones. Whichever form be used, the main considerations must be safety and freedom from breakdown, and, with these in view, the cable which carries its own mechanical protection and which is watertight is the best suited for the requirements of collieries, although, as shown by the last case quoted, special methods may be adopted to suit certain conditions, and, under those conditions, give the very best results.

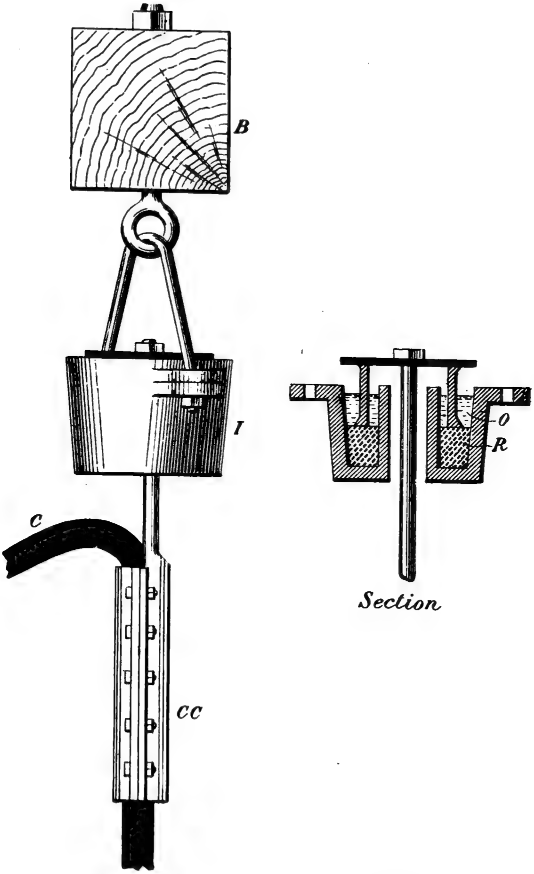


Fig. 14.—Shaft Cable Suspenders.

I = Insulator.	B = Wood beam.	O = Oil.
C = Cables.	C C = Cable clamp.	R = Indiarubber.

QUESTIONS.

1. It is desired to send a current of 100 amperes through a cable whose total resistance is 5 ohms. Find the pressure of the current.—*Ans.* 500 volts.

2. A current of 50 amperes passes through a circuit; the pressure is 210 volts. What is the resistance of the circuit?—*Ans.* 4·2 ohms.

3. A current of 100 amperes at 420 volts pressure is supplied to a motor. Neglecting friction, &c., what is the H.P. of the motor?—*Ans.* 56·3 H.P.

4. The output of a dynamo is 100 kilowatts, what is this expressed as H.P.?—*Ans.* 134 H.P.

5. Using the resistance given in the table, find the fall in voltage when a current of 29 amperes flows along a 7/15 cable one mile in length.—*Ans.* 43·4 volts.

6. A dynamo has an output of 100 amperes at an E.M.F. of 100 volts. If the efficiency of the dynamo is only 85 per cent., what B.H.P. must be applied to the driving pulley?—*Ans.* 15·7 B.H.P.

7. A 19/14 cable one mile long carries a current of 90 amperes. What is the loss in watts?—*Ans.* 3618·27 watts.

8. If the cable in question 7 has its length increased from 1 to $1\frac{1}{2}$ miles. (*a*) What is now the total loss in watts? (*b*) What is the increase of loss in watts?—*Ans.* (*a*) 5427·405, (*b*) 1809·135 watts.

9. A circuit, having a total current of 100 amperes passing, is divided into two branches, A and B. The resistance of A is 10 ohms and the resistance of B is 20 ohms. What number of amperes will pass in A and B respectively? and what will be the total resistance?—*Ans.* $66\frac{2}{3}$ amperes in A, $33\frac{1}{3}$ amperes in B; total resistance, 6·6 ohms.

10. A circuit carrying a total current of 74 amperes is divided into three branches, A, B, and C. The resistance in A is 8 ohms, in B 10 ohms, and in C 12 ohms. Find the quantity each branch will take, and the total resistance of the whole.—*Ans.* A takes 30 amperes, B takes 24 amperes, and C takes 20 amperes; total resistance is $3{\cdot}24\dot{3}$ ohms.

CHAPTER II.

THE THEORY OF THE DYNAMO.

Before commencing to describe the dynamo, it will be necessary to consider some of the elementary principles underlying its design and construction.

A **magnet** is a piece of steel or iron which has been endowed with polarity, and thus rendered capable of attracting other magnetisable bodies, and which, when freely suspended, assumes a direction parallel to that of the lines of force which traverse the earth's surface from the north and south magnetic poles.

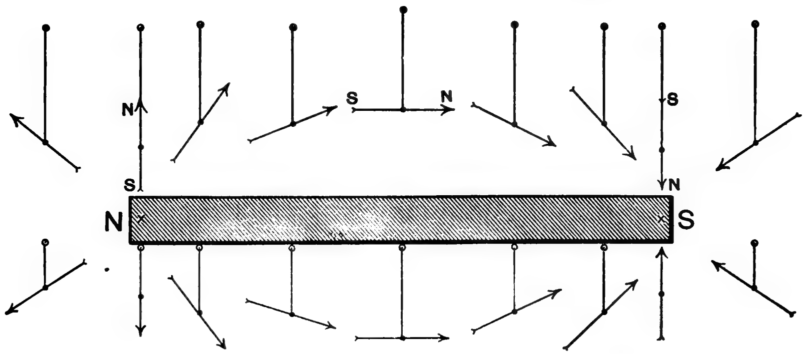


Fig. 15.—Direction of Magnetic Force round Magnet.

The ends of a magnet are also termed **poles,** the one which points to the north being called the north, +, or positive pole, and the one which points to the south the south, -, or negative pole.

The distribution of the **magnetic lines of force** which surround magnets can easily be determined by means of a small magnetic needle (Fig. 15), or by the positions assumed round the poles of the magnet by iron filings, the area of action of the force being called the magnetic field.

The magnetic force has "**point of application,**" "**direction,**" and "**amount or intensity,**" just as a mechanical force has, but only the two last named require further explanation when dealing with the dynamo.

Faraday regarded a magnet as a substance through which lines of force are passing, the lines being considered as entering at the south pole, and leaving at the north pole. The strength of the magnet is directly proportional to the number of lines of force which pass through it. This theory, while crude and unsatisfactory, will nevertheless serve to convey a concrete idea respecting magnetic force, which will serve its purpose in the discussion of the principles involved.

The lines of force of an ordinary horse-shoe magnet may be examined by placing a piece of cardboard over the poles and sprinkling some iron filings upon it. As the filings fall upon the card they arrange themselves in symmetrically curved lines between the poles of the magnet. Gentle tapping of the card may be necessary to obtain the best effects (Fig. 16). If a

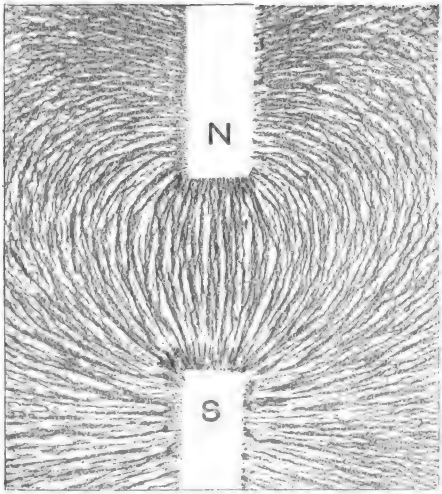


Fig. 16.—Lines of Force shown by Iron Filings round Poles of a Magnet.

permanent record is desired, a piece of blotting-paper which has previously been soaked in paraffin wax may be used in place of the card. Gentle heating with a spirit lamp after the filings have been put on, causes them to sink into the softened wax, on withdrawal of the heat the wax again solidifies and retains the iron filings in position.

Since the strength of the field is measured by the number of lines of force passing through unit area at that particular place, an examination of Fig. 16 will show that the strength is greatest

just between the poles. An accurate knowledge of the number of lines of force passing through a given substance is essential to dynamo design, but the subject need not be entered into here.

Although the nature of the electric current is unknown, the **magnetic effect** that it produces in its immediate surroundings is

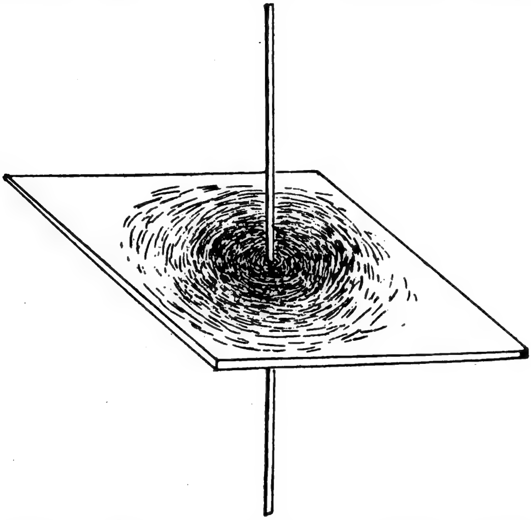


Fig. 17.—Lines of Force round a Wire carrying Current.

well known. Should a current be passed through a wire it generates lines of force in the surrounding space (Fig. 17). The lines form concentric circles round the wire, the magnetic effect decreasing with the distance, yet still, in many cases, extending some length.

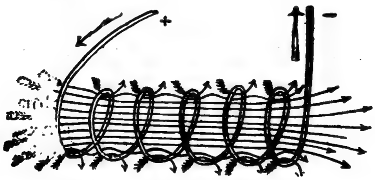


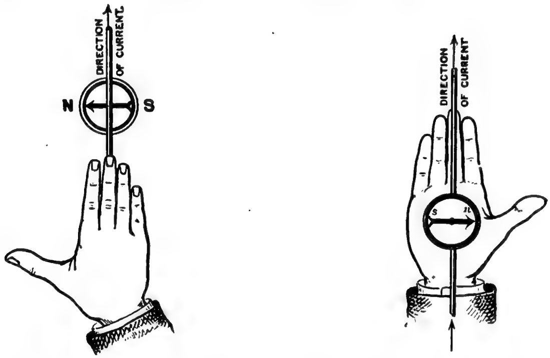
Fig. 18.—Magnet Field within a Solenoid.

Should the wire carrying the current be wound in a spiral coil, the arrangement is known as a **solenoid.** The distribution of the lines of force of such a system is shown in the accompanying diagram (Fig. 18).

Like a magnet a solenoid has north and south poles, but unlike a magnet its strength depends on the current passing through its coils. The **magnetic effect of a solenoid** is proportional to the current flowing through the wire, and also to the number of turns of wire forming the coil. For example, 1 ampere flowing through 100 turns of wire gives the same magnetic effect as 2 amperes flowing through 50 turns, or as 100 amperes flowing through 1 turn.

The product of the current in amperes, and the number of turns of wire in the coil, gives what is called the **ampere turns of the solenoid.**

The magnetic effect produced by a solenoid depends upon the ampere turns of the solenoid, and the **polarity of the solenoid** depends on the direction of the current through its coils, the poles changing upon reversal of the current.



Right hand above conductor. Needle below the conductor. Right hand below the conductor. Needle above the conductor.

Fig. 19.—Jamieson's Rule.

It is often of great practical importance in the coupling up of the field magnet coils of a dynamo, to be able to ascertain their polarity; to do this Professor Jamieson gives a very easily remembered rule, which is as follows :—

1. Move the conductor (if possible) into the magnetic meridian.

2. Place a freely suspended compass needle below or above the wire. The current will deflect the north-pointing end of the needle to the left or to the right.

3. Place the right hand, as it were, in the wire with the palm next to the needle so that the outstretched thumb coincides with the deflected north-pointing pole of the needle (Fig. 19).

Then the current flows along the wire in the direction indicated by the arrows to the negative (–) pole of the dynamo or source of current.

A soft iron bar inserted between the coils during the passage of the current through the solenoid immediately becomes strongly magnetised, the amount of magnetism thus induced depending on the ampere turns of the solenoid, as already stated. The increase of strength of the magnetic field is due to the fact that iron is a much better conductor than air, and consequently a larger number of lines of force pass through the iron than previously passed through the air gap between the coils, this increase continues, as the current increases, up to a certain limit, beyond which no further increase of lines of force is obtainable. The iron core, when this point is reached, is spoken of as being in a state of magnetic saturation. The coil of wire with the iron core constitutes an **electro magnet.**

This form of magnet is used to make the field magnets of the dynamo. The magnetism induced in the iron core continues so long as the current flows through the wire, on the stoppage of the current the magnetism of the core dies away, with the exception of a small residual effect, which depends on the quality of the iron. Even this small amount is, however, sufficient to make the machine self-exciting, and is known as the **residual magnetism** in the core or pole pieces.

As already shown, the flow of an electric current generates lines of force, and the converse is also true—namely, if lines of force are set up round a wire a current of electricity is produced in the wire. If a loop of wire be taken, and both ends connected up to a galvanometer, motion of the loop in the field of a magnet produces a current, which is shown by the deflection of the needle of the galvanometer. The current flows through the loop in one direction when the wire is moved towards the magnet, and in the other as it is drawn away. The same effect would be obtained by moving the magnet, and keeping the loop of wire stationary. It is important to note that the motion of the loop must not be in the same plane as the lines of force, but must cut through them, otherwise no current is generated. The passage of the loop through the lines of force does not of itself cause a current, but the change in the number of lines of force passed through does, and the strength of the current thus produced is proportional to the rate of change.

Fig. 20 may lead to a better understanding of this principle. The N and S poles of a magnet are here shown, with the loop of wire placed between them, in such a position that it is capable of revolving. The ends of the coil are connected up to

two half sleeves of metal, these sleeves are pressed on by two metal strips which are fixed in position and connected to the wire which forms what is called the **outside circuit.** The motion of the coil towards, and away from the poles, produces currents which change their direction during each revolution, starting at zero and increasing to a maximum as the coil approaches a pole, and decreasing from a maximnm to zero as the coil recedes. The currents pass through the loop to the two metal half sleeves, from the half sleeves to the brushes, and thence round the outside circuit. The current, although alternating in the loop, is continuous in the outside circuit, because at the moment the current in the loop changes in direction, the half sleeves interchange brushes, each brush thus receiving its current always in the same direction. This arrangement of half sleeves is called

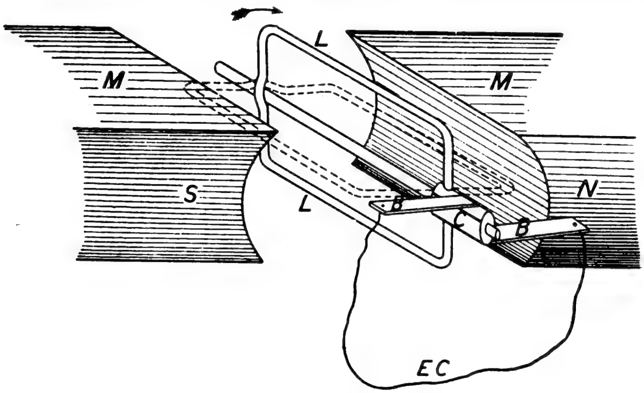


Fig. 20.

B B = Brushes. | M M = Magnets.
C = Commutator. | E C = External circuit.
L L = Loop of wire.

a **commutator,** and is a necessary part of all continuous current machines.

The effect of this commutation is shown in Fig. 21, the base line A B being the angle turned through in one revolution, while the heavier curved line shows the fluctuation of the E.M.F.

To reduce the fluctuation several coils of wire are used in practice, the ends of each coil being connected up to copper bars, each bar being insulated from the other. This gives a machine of what is known as the **open coil type.** Such machines are

not well suited for ordinary work, and are seldom used about collieries. Instead of joining up the coils of wire, as in the above, all the coils should be connected together and the junction of each adjacent pair connected up to a bar on the commutator, so that the whole of the wire forms a complete electrical circuit, independent of any connection which may be made by means of the brushes to the external circuit. In such an arrangement we have what is known as a **closed coil armature.**

In the open coil armature the current is collected from a coil when that coil is in the position of maximum activity, the coil being thrown out of circuit after this position is passed, another coil coming forward to take up this position and in its turn furnish its share of the current thus generated.

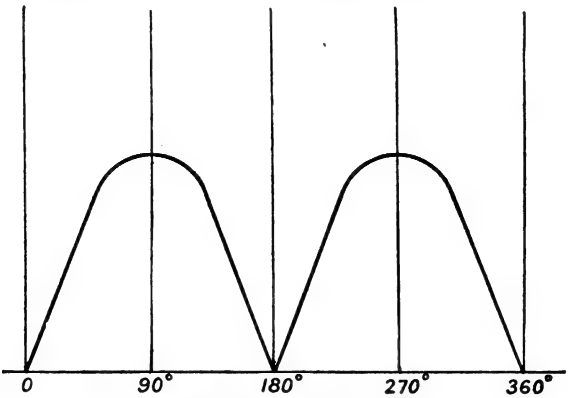


Fig. 21.—Curve of E.M.F.

In the closed coil armature the current generated in every position, except at the moment it is short circuited by the brushes, forms part of the total, and finds its way through the external circuit. This class of armature is much better adapted to ordinary requirements than the open coil type; and closed coil machines are those we find in general use.

In practice the coils or loops of wire are wound upon an iron drum, which from the mechanical point of view gives greater strength and efficiency, and at the same time enormously increases the lines of force passing between the poles of the magnet by substituting iron for air. These loops of wire, together with their iron core, are known as the **armature** of the dynamo.

As already pointed out, the flow of a current round an iron core produces magnetic effects in the iron, and we see that from

this cause the armature core will have N and S poles developed. Thus we have two opposite magnetic effects both going on at the same time, the magnetic flux of the *fields*, which produces the E.M.F.; and that produced by the magnetisation of the

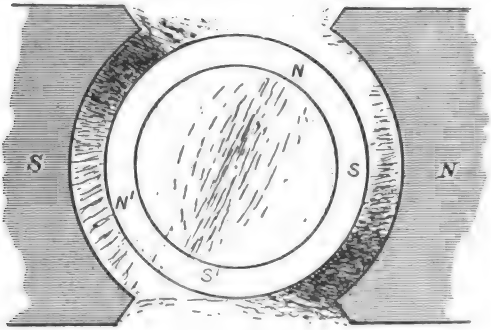


Fig. 22.—Lines of Force distorted by Cross Magnetism.

armature core, which has a wasteful effect and tends to distort the natural field; this distortion of the field is shown in Fig. 22.

When the current leaves and returns to the armature by means of two brushes which rest on the commutator, they are

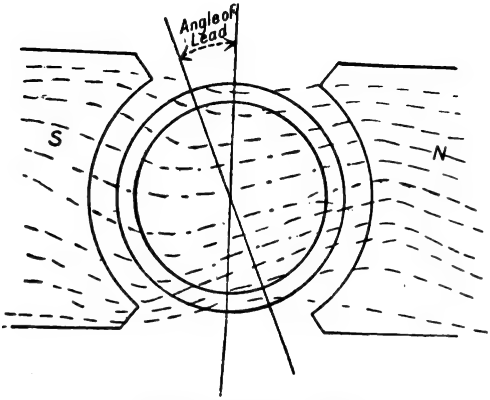


Fig. 23.—Angle of Lead.

diametrically opposite to each other, and if no distortion of the magnetic field occurred, would rest in a vertical position. But in order to prevent sparking it is necessary to make the brushes rest at right angles to the mean direction of the field. The

angle between the direction of commutation and the vertical is called the **angle of lead** (Fig. 23).

Other sources of loss are **eddy currents** and **hysteresis**, the first being due to the fact that iron is a conductor, and if a solid armature be used, large currents of low potential are generated in it, by rotation in the magnetic field. These currents, often called Focault currents (after their discoverer), would cause undue heating of the armature, and to prevent this armatures are, in practice, usually built up of thin plates of soft iron insu-

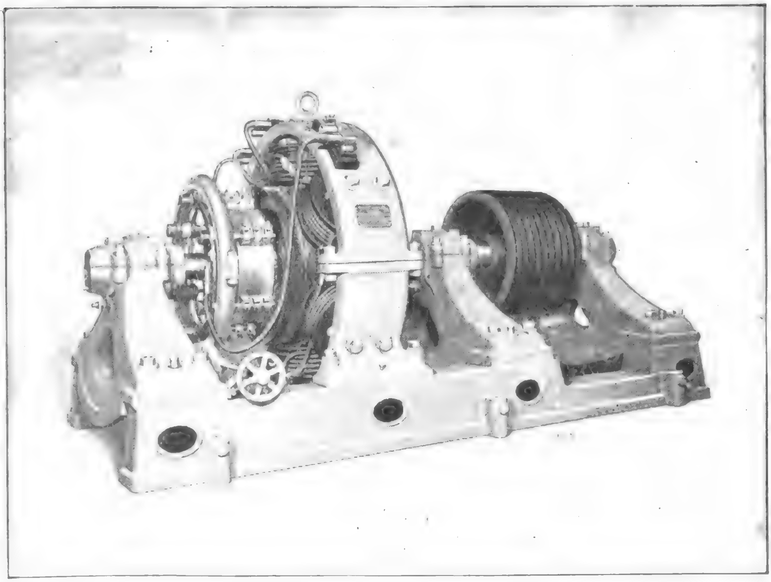


Fig. 24.—Continuous Current Dynamo.

lated from each other, by varnishing or inserting thin paper between the plates or laminations, as they are called.

Hysteresis is due to the rapid reversal of the direction of magnetism in the iron core, and may fitly be termed magnetic friction. As the poles of the armature change as the armature rotates, hysteresis is set up, but in practice its effect is reduced to a minimum by using suitable iron in the armature.

As already noticed the brushes change from one section of the commutator to another at the moment the current reverses, and

since the circuit possesses self-induction it is impossible to start or stop the current instantaneously. This condition of matters would cause serious sparking at the commutator if allowed to exist. It is, however, prevented by making the brush thick enough to bridge over two or more commutator sections. This causes a momentary short circuit in the coil as it passes the brush, and allows the current time to expend itself gradually before one is set up in the reverse direction. Not only does this allow the current to die out, but the coil is allowed to travel far enough into the opposite field, to allow some E.M.F. of opposite sign to be generated, so that no trouble in starting the reverse current in the coil is experienced.

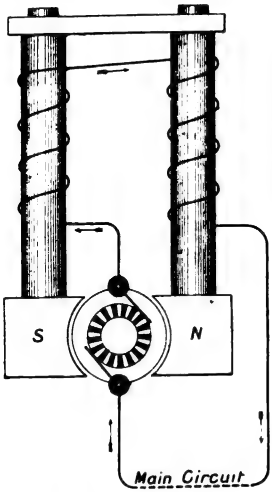


Fig. 25.—Series Winding.

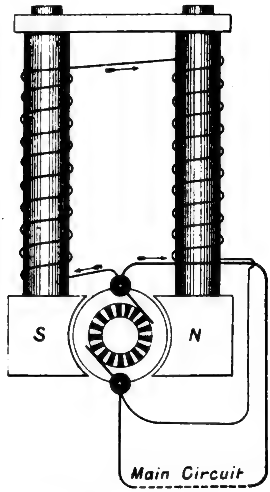


Fig. 26.—Shunt Winding.

The machine described is known as a **continuous current dynamo**, of which Fig. 24 gives a general idea.

Continuous current machines are of three classes, and are classified according to the method of winding the field magnets, as—

(*a*) **Series wound machines.**
(*b*) **Shunt wound machines.**
(*c*) **Compound wound machines.**

(*a*) In *series winding* the arrangement of coils provides for the whole of the current flowing from the + brush through the

windings of the field magnets, then through the external circuit and back to the negative brush. This form of winding is suited for arc lighting, or for conditions that require a constant current. The wire used in winding the field magnets is of large diameter and low resistance. Thus a comparatively small number of turns upon the field magnets produce the complete magnetisation of the field. Fig. 25 is a diagrammatic representation of this form of winding.

(*b*) In *shunt winding* two paths are open to the current. As it leaves the + brush the current divides, one part flowing through the coils of the field magnets, the other part flowing through the external circuit. Both join at the – brush before

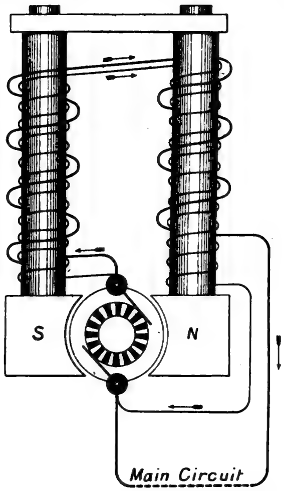


Fig. 27.—Compound Winding.

their return to the armature. This form of winding is suited to conditions where a constant E.M.F. has to be provided under varying conditions in the external circuit. The wire used in winding the fields is of small diameter, and consequently of comparatively high resistance. A large number of turns is wound upon the fields. Fig. 26 is a diagram which represents this form of winding.

(*c*) *Compound winding*, as the name implies, is a combination of both shunt and series winding already described. This combination enables the dynamo to give a constant E.M.F. within a very wide range of working. The shunt coils consist of many turns of thin wire, and are overlain by the series coils which

consist of a few turns of thick wire, both being coupled up, as shown in Fig. 27. In this diagram the shunt coils are shown by a thin line, while the series coils are shown by a heavy line.

Another class of compound winding consists in having an increased number of series coils, as compared with the ordinary compound winding. This increase of the series coils causes the voltage to rise, should the load upon the machine be increased. This arrangement makes up for any loss of pressure that may take place in the circuit. Such a machine is said to be over-compounded. In cases where it is necessary to vary the degree of over-compounding the series coils may be provided with resistances, so placed that the current passing through the coils can be regulated. This of necessity allows for the regulation of the E.M.F. given out by the machine.

If, in place of the commutator, two insulated rings are placed on the armature shaft, one end of the armature coils attached to

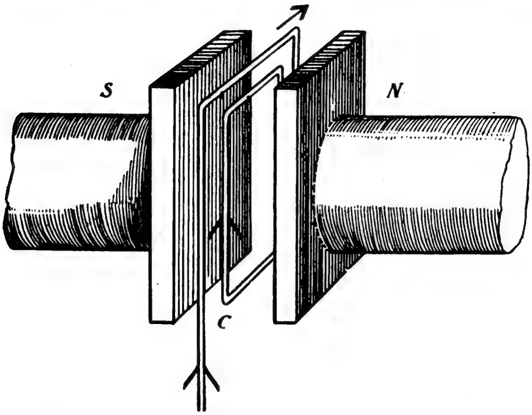


Fig. 28.—Coil and Poles of Siemens Alternator

one ring and the other end to the other ring, a current is obtained which changes its direction twice during each revolution of the armature. Such a current is known as an alternating current, and machines built for the supply of currents of this type are known as alternators.

In practice these machines are made of various types, but so far they have been little used about collieries. A short description of the Siemens machine, which is typical of this class, will, however, be given, as polyphase currents are being adopted for mining work, and are generated upon the same principle as alternating currents.

If two poles, N and S (Fig. 28), which are north and south poles, have lines of force passing between them, and a coil of wire be moved into the position marked C on diagram, a current will be induced in the coil, and will flow in the direction marked by the arrow so long as the cutting lines of force are on the increase, but immediately the coil passes the position where those lines are a maximum, and enters a weaker part of the field, the current is reversed.

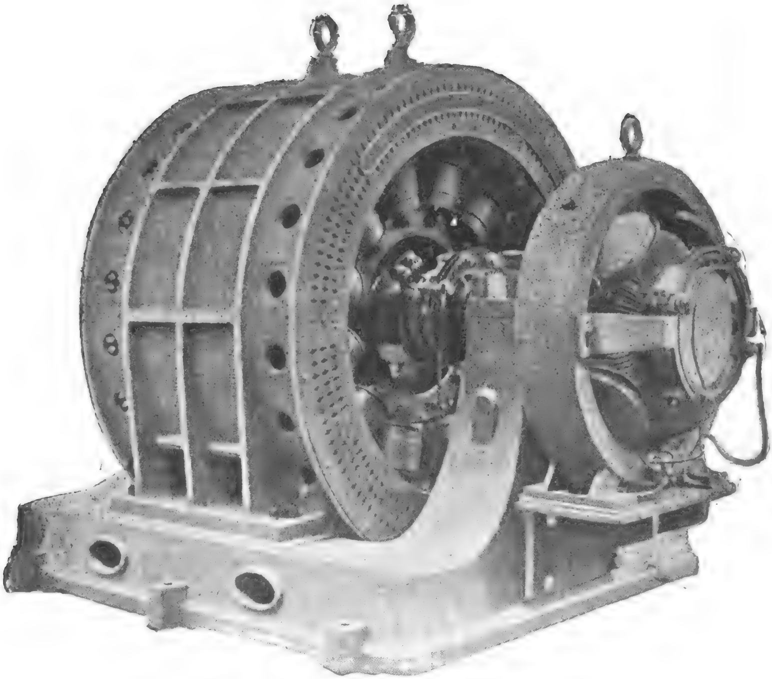


Fig. 29.—Three-phase Current Generator.

In the **Siemens alternating current dynamo** a number of such poles are fixed on two vertical cast-iron rings, the whole being secured to a suitable bed plate. The poles are excited by a small continuous current machine, which is driven from the alternator. The field magnets are arranged alternately north and south, so that the current in an armature coil changes its direction as often during each revolution as there are pairs of field magnets. The armature has as many coils symmetrically

arranged as there are pairs of field magnets. Two insulated rings, which are fixed on the shaft, collect the currents which are generated in the different coils.

An inspection of the armature would show that only a portion of it is occupied by the coils, and that they are spaced at equal distances apart. Should a second set of coils, similar to the first, but not connected to them, be wound in the spaces between the first set, rotation of the armature will now produce two set of currents, the one leading the other by half a period. In the same way if three sets of independent coils equally spaced are wound upon the armature, three currents would be obtained when the armature was rotated, each reaching its maximum one-third of a period in front of the other. Such machines furnish what is now known as polyphase or multiphase currents.

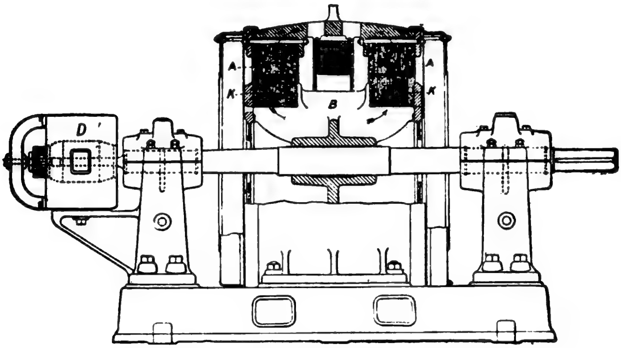


Fig. 30.—Section of Three-phase Generator.

The currents thus furnished pass through a regular series of changes, both in magnitude and direction, the time in which this cycle of changes is completed being termed the period, and the number of cycles completed per second is termed frequency.

The frequencies adopted in practice vary with different firms, but for purposes of power transmission are often fixed at 25 and 40 cycles per second and in some cases even higher.

In practice various types of generators are in use; some (as in the Siemens machine described) have a stationary field magnet with rotating armature, others have the magnets rotating and the armature stationary, while a third class have both the field magnets and armature stationary, the induction being varied by the rotation of suitable masses of iron called inductors.

A machine of the latter class is shown in Fig. 29, the absence

of any windings on the rotating parts allow of high mechanical strength being obtained, and does away with the necessity of brushes or collectors of any description. A section of one of these machines is shown in Fig. 30. The exciting coil, X, is supported from the body of the machine, and is fed by the small direct current dynamo, D, which is coupled by an extension of the armature shaft, a flow of magnetic force being induced, as indicated by the arrows. The armature cores, A A, are built up of laminated iron plates to form complete cylinders, and the armature conductors are placed in tunnels left in the cores near the inner circumference. The other half of the magnetic circuit consists of a series of laminated projections, K K, bolted and dovetailed into the revolving centre, B, laminated blocks or keepers being placed at intervals round each end of this revolving centre.

The resistance to the flow of magnetic lines is thus a constant for every position of the revolving keepers. The only difference made, as this part revolves, is in the position at which the current leaves the armature core, A. This core is provided with 8 sets of bars for each phase. The conductors of one phase are equally spaced at intervals round the inner circumference of the core, A, and the action will be more easily understood if one phase be considered by itself. When the keepers, K K, are directly opposite these coils the whole of the current passes through them, giving the zero point of the E.M.F.

As the machine revolves the keepers withdraw the current from the coils until they have moved, so as to be equally spaced between two coils. In this way an alternating E.M.F. is obtained without either of the copper circuits revolving. The three-phase windings are spaced round the armature, so as to have E.M.F.'s generated in them varying in phase of 120°. The armature bars of each phase, after being connected in series, have one free end connected to a common terminal, and the other connected to one of the three terminals of the machine. This gives what is known as the star method of connection, which will be dealt with more fully later when considering the cables connecting the generator with the motor.

CHAPTER III.

THE DYNAMO.

A DYNAMO is a machine for converting mechanical energy into electrical energy. As shown in the last chapter, dynamos are of two main classes:—(1) Those that furnish a continuous current, and (2) alternating current machines. The former is the class of machine in general use about collieries, and will be described first.

Continuous Current Dynamos.—As has been already stated the continuous current dynamo consists of the field magnets,

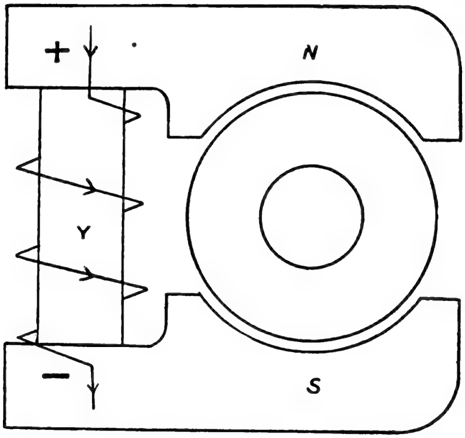


Fig. 31.—Salient Pole Type.

N = North pole piece. | S = South pole piece.
Y = Yoke.

armature, and commutator, the functions of each of which have already been dealt with. Although practically similar in principle, the details of the machines now on the market vary with different makers, each having their own particular design. As a rule, the armatures do not differ from one another to any great extent, but the field magnets assume various forms, although they may be divided into two main classes—viz., those with "**salient**" poles, and those with "**consequent**" poles. The

term "salient" is employed when the poles are produced at the ends of a bar of iron. Should, however, the poles be produced in a continuous ring of iron the term "consequent" poles is employed.

In practice the salient pole type is the one most frequently met with, owing to its greater simplicity of construction. Fig. 31 shows, diagrammatically, a common form in which the magnetising coil is wound upon the yoke, which is usually of wrought iron, let into and bolted to the pole pieces. The latter

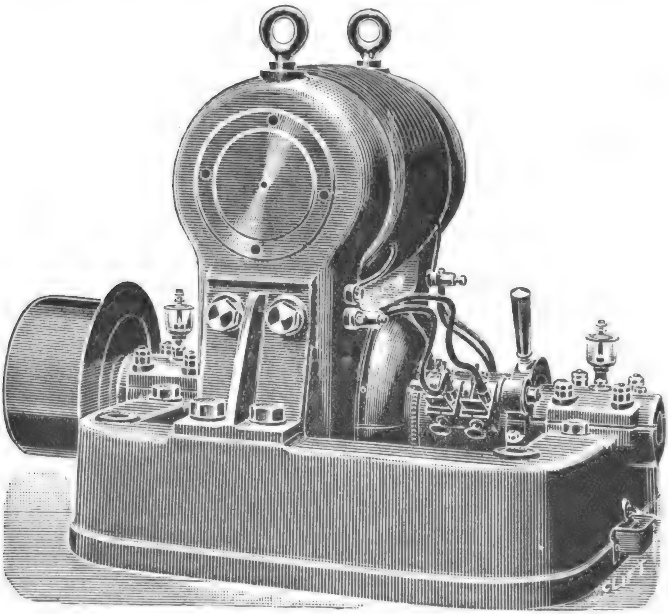


Fig. 32.—Dynamo Salient Pole Type.

are supported from the bed-plate by two strong gun-metal brackets, in order to magnetically insulate them, as far as possible, from the bed-plate. Fig. 32 gives a representation of such a machine.

Another very common form is that known as the "undertype," and is extensively used in large machines, as freedom from vibration and stability is secured by the centre of gravity of the revolving armature being placed low. Fig. 33 is a diagram showing this form. The field magnets are usually made of

rectangular slabs of wrought iron, bolted together at the top to a wrought-iron yoke, the whole being supported from the cast-

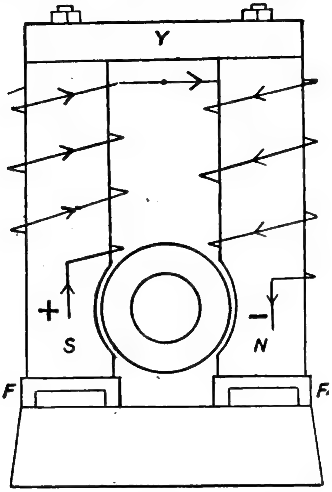


Fig. 33.—Salient Pole Type.

N S = North and south poles. | F F = Brass footsteps.
Y = Yoke.

iron bed-plate by means of brass or gun-metal footsteps, so as to secure magnetic insulation.

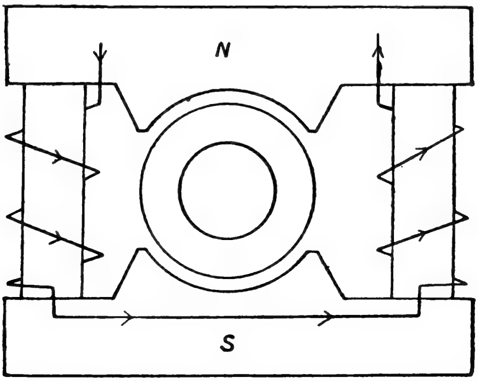


Fig. 34.—Consequent Pole Type.

N = North pole. | S = South pole.

The "**Manchester**" type of machine may be taken as illustrating a common form of "consequent" pole dynamo. Fig. 34 shows diagrammatically the winding system adopted in the above form. So far all the machines dealt with have been bipolar, but multipolar machines are now being used to a considerable extent, as, for a given output, they are more compact and lighter than bipolar dynamos. They may be either salient or consequent pole machines, but by far the greater number of this class belong to the consequent pole type.

The number of poles may be four, six, eight, or more, the windings being arranged so as to produce a north and south pole alternately. Fig. 35 shows a diagram of the winding of a six-

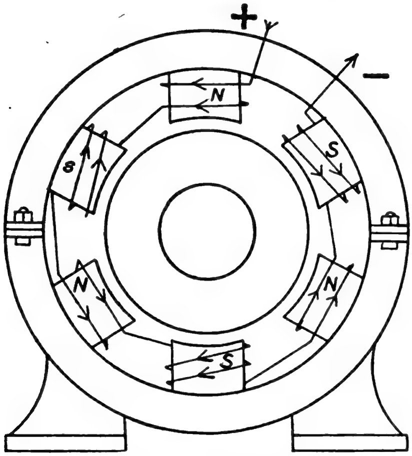


Fig. 35.—Consequent Pole Type.
N = North Pole. | S = South Pole.

pole dynamo. It is usual to have the ring which carries the pole pieces made in two parts, so that the top part can be readily removed to allow access to the armature.

The windings of the field magnets are, as a rule, carried by bobbins, which are made to slip down over the pole piece. This makes the winding an easier matter, and also aids their removal from the pole piece should this become necessary. The wire used is generally of solid copper, well insulated, the size depending on the design and output of the machine. In shunt-wound machines the wire used is very thin, and is rather liable to be broken where it leaves the coils. To prevent this it is often soldered to a stronger wire, the joint being so placed that it will

be protected by the flanges of the bobbin, and the coupling-up being effected by means of the stronger wire.

In coupling-up field magnet coils it is necessary to arrange the connections, so that the flow of current will produce the required polarity in the respective pole pieces. This is easily done by the aid of Professor Jamieson's rule, already given on p. 25. The diagrams shown in Figs. 25, 26, and 27 will also be useful in this respect.

Armatures.—Armatures may be divided into two classes—namely, **ring** armatures and **drum** armatures. For power transmission the drum armature has the great advantage of being

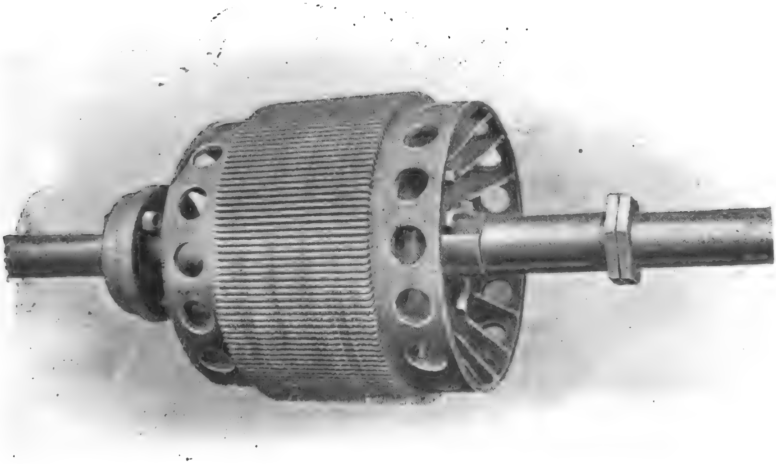


Fig. 36.—Complete Core of Drum Armature.

much stronger mechanically, and for that reason is the one in more general use, although the ring type is still preferred by some electricians.

In the ring or gramme armature, as it is often called, a laminated charcoal-iron ring is supported from the armature shaft by means of spiders, and on this ring is wound a number of coils of insulated copper wire, so as to cover the whole surface of the ring. The ends of each coil are connected to the one adjacent, and also to the commutator, thus forming a continuous spiral all round the iron ring, and having each point of junction of the various coils connected to a commutator bar.

In the drum armature the core is built up solid, with thin plates of Swedish charcoal-iron, insulated from each other by thin paper or Japan varnish, and clamped firmly together between strong end plates of gun-metal or cast iron. Fig. 36 shows the core of a drum armature. The surface of the armature is slotted in a direction parallel to the axis, and the insulated armature windings are laid into these slots. In all modern machines these windings are so arranged that each individual coil is entirely separate from the remainder, so that if repairs are required any single coil can be taken out without interfering

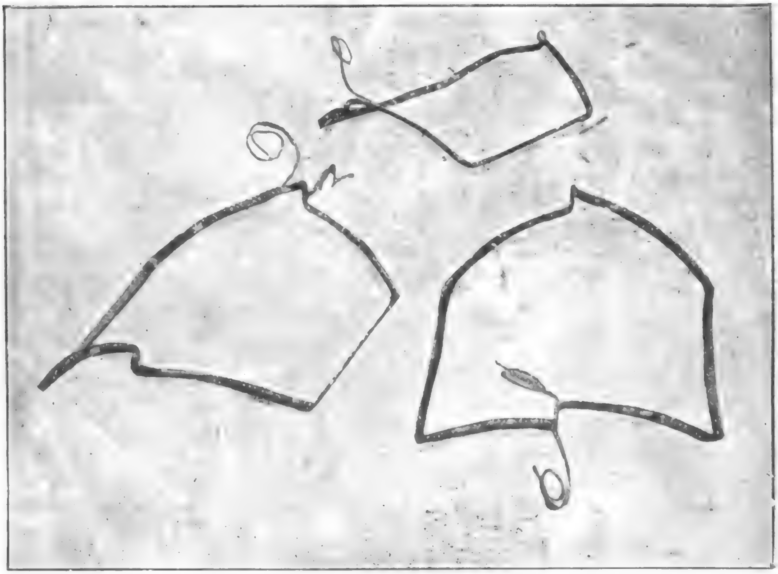


Fig. 37.—Formed Coils ready for putting on.

with more than a few of the others. This is effected by winding each coil upon a *former*. This is practically a *pattern*—*i.e.*, an appliance of such a shape that the coils wound upon it take the necessary shape for their symmetrical arrangement on the armature core previous to putting it into position on the armature. Such coils after being bent into shape are taped and varnished previous to being put into position. Fig. 37 shows three of those coils ready for fixing on the armature; while Fig. 38 shows an armature which is being wound in this way partly

completed. The projecting ends of the armature windings are connected into copper strips, which project from the commutator bars by sweating. The removal of a damaged section is thus rendered easy.

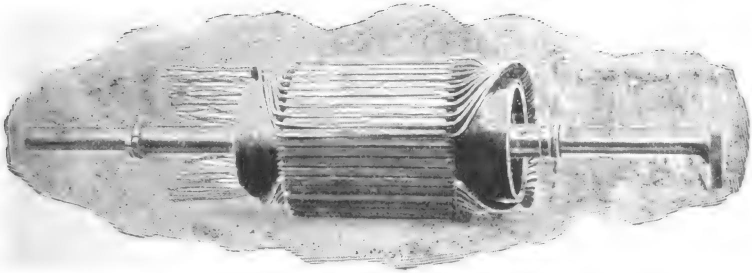


Fig. 38.—"Former" Winding being put on.

Commutators.—The commutator is built of the required number of sections, which should be of hard-drawn copper, each section being insulated from the other by thin sheets of mica, and the whole being held in position on a gun-metal sleeve

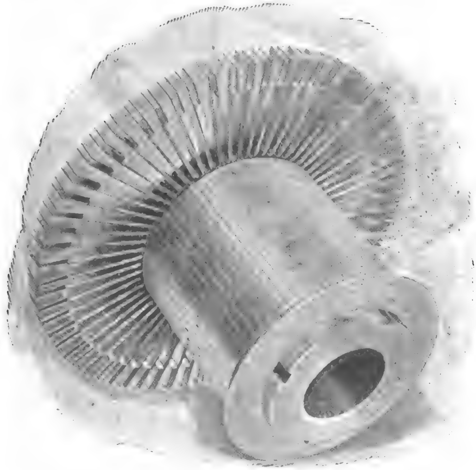


Fig. 39.—Commutator and Connecting Lugs.

by means of wedge-shaped circular rings at each end. A commutator, with its connecting lugs, is shown in Fig. 39.

In placing the formed coils into the slots, mica or "presspahn" insulation is also employed, and after the whole of the coils

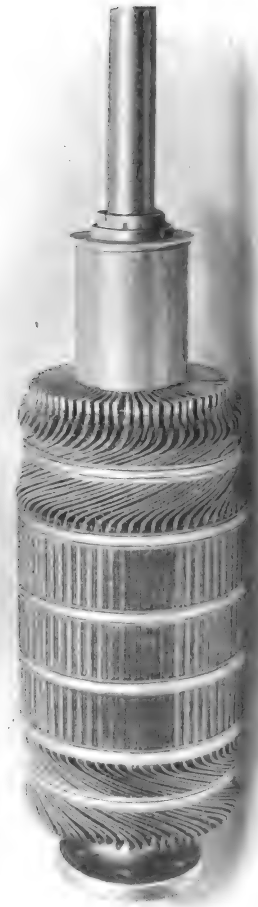


Fig. 40.—Complete Drum Armature.

have been placed in position they are firmly secured in their places by means of binding wires, which gives the armature a very compact and practically solid structure. A completed armature of the drum type is shown in Fig. 40.

The binding wires used should be of steel possessing a high tensile strength, and should be wound under tension upon bands of fibre or mica, and soldered together with ties at frequent intervals, as they have to stand considerable pull, due to the drag of the magnetic field upon the periphery of the armature, as well as the straining due to centrifugal force, which, in high-speed machines, may be of considerable magnitude.

The **brushes** for collecting the current vary in number according to the number of poles on the machine, one set of brushes being required for each pair of poles. Their function is to collect the current from the commutator. Brushes may be of wire gauze, folded and compressed, or small blocks of carbon, coated with copper. The brushes are attached to a brush rocker, which allows of their position being varied, and they are made to bear upon, and make sliding contact with, the commutator by means of springs. Carbon brushes are much to be preferred, as they do not wear the commutator to the same extent as gauze ones, and are not nearly so bad for sparking.

The **bearings** which support the armature are a very important part of the machine, and should be of the self-oiling type, with loose rings revolving on the spindle, and dipping into an oil-well formed in the pedestal. Such bearings will run cool for a long time without attention. The length of the bearing surface is also of great importance, and should never be less than two and a-half times the diameter of the shaft for each bearing. With small machines two bearings, with the driving pulley overhung, will serve the purpose, but in large machines the bed plate should be extended to carry a third bearing, which is fitted upon the outside of the driving pulley.

Where dynamos are not direct coupled, they are driven either by **cotton ropes or belts.** The most common method is by means of belting. Raw-hide belting is the best for this class of work, but several of the cotton and guttapercha belts now on the market give very satisfactory results. In large machines where the speed is low, light double or link belting may be used where single belting would not transmit the requisite power. The joint of the belt should always be spliced flush, cemented, and sewn, as this prevents fluctuation of the speed when the joint passes over the driving pulley. The pulleys should always be of sufficient size and width to give ample gripping surface for the belt, otherwise there will be excessive slip.

The following table will be useful in determining the size of belt to transmit a given horse-power :—

Speed of Belt in Feet per Minute.	H.P. per Inch Width of Effective Gripping Surface.			
	Single Leather.	Double Leather. Light.	½-Inch Leather Link.	⅝-Inch Leather Link.
500	·75	1	·75	·90
600	·90	1·25	·9	1
700	1	1·5	1	1·25
800	1·2	1·75	1·2	1·4
900	1·4	1·9	1·35	1·6
1000	1·5	2·2	1·45	1·75
1200	1·5	2·5	1·45	2
1400	2·1	3	2	2·4
1600	2·4	3·4	2·3	2·75
1800	2·75	3·8	2·65	3·1
2000	3	4·25	2·9	3·4
2200	3·3	4·5	3·2	3·8
2400	3·6	5	3·5	4·1
2600	4	5·5	3·8	4·5
2800	4·25	6	3·85	4·75
3000	4·5	6·3	3·85	4·75
3200	4·7	6·8		
3400	4·8	7·2	Speed limit of efficiency.	
3600	5	7·4		
3800	5·05	7·5		
4000	5·09	7·6		
	Speed limit of efficiency.			

Pulleys should be slightly wider on the face than the belt used.

Belts should not be allowed to become dry or stiff, and powdered resin should not be used unless on an exceptional emergency, and where no other method of increasing the grip of the belt is possible.

Castor oil, well rubbed into the belt, forms a very good dressing and keeps the belt in good running condition.

When cotton ropes are used for driving they are usually fitted in series of six, eight, or more ropes which run in correspondingly grooved pulleys. The pulleys should be made so that the gripping surface is on the *sides* of groove, and when the ropes are so worn that they bed on the bottom they should be renewed. Ropes should be well spliced, and should not be overtight as they shrink perceptibly in damp weather. In arranging the direction of running it should be remembered

that if the slack side be made the top any sag will tend to increase the gripping power, whereas if the lower side be made the slack side the reverse is the case.

Careful attention to the machine while working is of considerable importance, and the following instruction as to "How to look after a Dynamo," by W. C. Mountain, may be quoted:—

"On the arrival of a dynamo at the place where it is to be fixed the cover of the packing case should be taken off, and the machine carefully examined, to ascertain if it has got damp or injured in transit, the cover should then be replaced, or the machine carefully unpacked and put in a dry clean place, and covered with a canvas or waterproof cover until the foundations are ready."

"Too great stress cannot be laid upon the importance of having good solid foundations, as it must be borne in mind that a dynamo is a high-class piece of quick-running machinery, and unless firmly and securely fixed it will vibrate and knock itself to pieces, whereas if well fixed it should run for years with ordinary care and attention."

"The foundations should be made of brick, concrete, or stone, preferably brick or concrete with a stone about 12 inches thick on the top; if of brick it should be built in cement, the stone being bedded in cement at the top of the brickwork."

"With large dynamos it is advisable to carry the holes for the holding-down bolts, which should not be less than 4 inches square, to the bottom of the foundations, and build in a cast- or wrought-iron holding-down plate, with a square hole in the plate of a suitable size to take the bolt and prevent it turning when being screwed up. Under the holding-down plate a hand hole should be left to enable the cotters to be readily got at."

"In building the foundations the simplest plan to form the holding-down bolt holes is to make some taper wooden boxes about 3½ inches square at the bottom and 4½ at the top, and build them in; they are withdrawn when the foundations are finished."

"For small machines it is not necessary to take the bolts through the foundations, a very simple and efficient plan being to cut some square holes in the stone slab, the holes being made to taper outwards slightly—*i.e.*, smaller at the top than the bottom—jagged Lewis bolts, with the skank tapered down towards the thread, being placed in the holes, and run in with lead, sulphur, or cement."

"It should be carefully remembered that foundations are no use unless on a good bottom, and they must be taken deep enough to obtain this."

"In all cases it is advisable to fix the dynamo upon a sliding cast-iron bed plate with brackets and tightening screws for taking up the slack of the belt; but whether this is done or not, the following remarks will apply:—

"Take a spirit level and straight edge and see that the top of the foundations are level and dressed off true. Having ascertained that they are so, have the bed plate (dynamo or sliding bed) lifted carefully on to the foundations, having first placed the holding-down bolts in position, then level the machine or bed by placing thin taper wooden wedges under the corners and sides if any great length, tapping them in until the bed is level each way. Before proceeding to finally level, it is advisable to ascertain that the machine is set square with the shafting or flywheel. This is found by taking a fine cord line and stretching it across the faces of the main driving pulley or flywheel and dynamo pulley; if the cord is straight and touches the two edges of the main driving pulley and the two edges of the dynamo pulley, the machine is set square."

"In cases where the main driving pulley, or dynamo pulley, is wider on the face than the other an allowance can readily be made, and the distance from the edge of the cord and the pulley measured off on both edges."

"Having set the bed plate square and level, the holding-down bolts being in their place, or if Lewis bolts are used the holes having been marked off when the machine was first put on its bed, and the holes cut in a stone and the bolts dropped in their place, the machine is ready for grouting in."

"With holding-down bolts passing through the foundations, this is done by stopping up the crevices where the bolts pass through the holding-down plates with clay, and also putting a small wall of clay round the bed plate, leaving 1½ inches clear all round. This forms a sort of pound, and into this a thin liquid cement is poured until the holding-down bolt holes are full and the thin cement has got well between the bottom flange of the bed plate and the stone. When the cement is set the nuts on the holding-down bolts which had previously been left slack are screwed up, and the machine is firmly secured."

"If Lewis bolts are used they must be run in with lead or sulphur and the machine grouted as described."

"The machine should be carefully examined, to see that it is ready, and in a fit condition to be started."

"The main bearing caps should be removed, and the spindle and bearings cleaned from dirt and grit; then well oiled and the caps replaced, the nuts being screwed up with the fingers only. The armature and spindle should be turned round in the bearings to see that they run free."

"The commutator must next be examined to see that it has not been injured in any way, and that none of the sections have got knocked in. Before any current is taken from the machine the commutator should be polished with a piece of fine worn emery cloth, the brushes having first been raised, otherwise emery dust would get under the brushes and cause cutting of the commutator."

"The brushes and brush holders must then be examined to see if they are clean and working freely. A stiff paint brush is useful for dusting the brushes and holders, and is afterwards useful for removing any brass or copper dust which might accumulate. The brushes should then be lowered on to the surface of the commutator, and must bear with a soft elastic pressure. If they bear too lightly they will jump off when running and cause sparking, and if too hard they will cause cutting."

"The brushes must then be examined to see that they bear in the right position on the commutator—*i.e.*, that there are the correct number of copper sections between each brush. It is usual to put centre-punch dots on the sections on which the brushes should bear; but if this is not the case the sections must be counted, and in a two-pole machine the brushes must bear on exactly opposite sections, in a four-pole machine at exactly one-quarter of the total sections apart. For instance, in a commutator with 72 sections the brushes of a two-pole machine would be 36 sections apart; with a four-pole machine 18 sections apart."

"The brushes having been adjusted, the bearings well oiled, and the lubricators either made to feed fast, or better still removed, and the connections examined, the machine is ready to start; but before starting the main switches should be opened and the brushes raised."

"Then let the machine run empty for some time to see that the bearings run cool, and that the machine is all right mechanically."

"The machine should then be stopped and the brushes lowered on to the commutator, the points of the brushes being placed on the neutral line, which is the centre line between the poles."

"If an incandescent lighting installation, the main switch should be closed and the machine started, the speed being gradually increased until the voltmeter or a pilot incandescent lamp registers the correct voltage; the brushes may then show signs of sparking, and they must be rocked backwards and forwards until they attain a position where sparking disappears. This position should be carefully noted, and the brushes always placed, before starting, as nearly as possible in this position."

"In some dynamos the angle of lead—that is, the distance the brushes have to lie over the centre line—varies with the load. Therefore if any lamps are switched on or off, it is necessary to alter the position of the brushes. If this is not attended to sparking and wearing of the commutator and brushes result."

"The dynamo having been started, a few hints are necessary to keep it in proper running order, as many people imagine that a dynamo, unlike other machinery, will run without attention. This is not the case, and proper care soon repays the owner."

"The bearings must be carefully attended to, and kept well oiled. It is usual on all good machines to supply adjustable sight feed lubricators, and these must be adjusted so that the bearings are well but not wastefully lubricated. The waste oil should be collected in trays, and, after being carefully strained, may be used over again several times. The bearings should be kept so adjusted that they run cool, but do not knock or cause vibration. The commutator, which is a most important part of the dynamo, also requires attention."

"When the time for closing down comes the dynamo should be stopped with the switches on, except in the case of arc lamps, the incandescence of the filaments of the incandescent lamps being gradually reduced. When the dynamo is at rest, or only revolving slowly, the brushes should be raised and a piece of worn emery paper held under the commutator, the machine being then run at a moderate speed. This removes any roughness from the surface of the commutator, which is finally cleaned by applying a piece of soft oily rag or white cotton waste; it is then ready for the next spell of work."

"Whilst the machine is running the surface of the commutator should be very slightly lubricated by a piece of clean rag moistened with mineral oil, or better still with vaseline; this will keep it from cutting."

"If the above precautions are taken the dynamo will run for years without trouble."

In running dynamos it occasionally happens that faults of some kind or other are met with; these may be due to accident, neglect, or wear and tear; but from whatever cause they arise they will have the effect of either partially or completely disabling the machine.

To locate faults it is necessary to have a testing battery and galvanometer, the tests usually being either for conductivity or insulation.

In making the test for conductivity the positive pole of the battery is connected to one of the terminals of the galvanometer. while the negative pole is connected to one end of the wire

which it is desired to test, the other end being connected to the other terminal of the galvanometer. As soon as the circuit is closed the needle of the galvanometer should be deflected; if, however, a break exist, no deflection will take place. Care must be taken while making this test to see that all the connections make good contact, as mistakes may be made by neglect of this precaution.

The arrangement of the battery, galvanometer, and coil of wire under test is shown in Fig. 41.

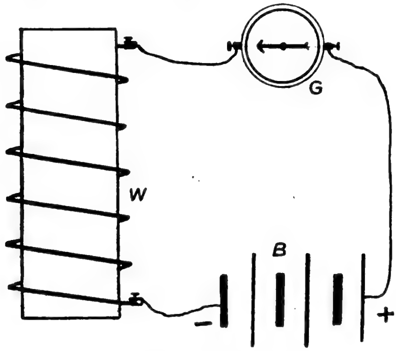


Fig. 41.—Test for Continuity.
G = Galvanometer. | W = Coil of wire under test.
B = Battery.

In testing for insulation, the object is to find whether the wire is completely insulated from any metal round which it may be wound, as, for instance, the core of a magnet. To accomplish this, one terminal of the battery is fixed to the one end of the wire, the other terminal being connected to the galvanometer. A small piece of the metal core is scraped clean with a knife, and a wire, connected to the other terminal of the galvanometer, is made to touch the place thus cleaned. Should the insulation of the wire be imperfect, and some part of the bare wire be in contact with the metal core, the needle of the galvanometer is deflected at the moment the core is touched with the connecting wire. If, on the other hand, no deflection takes place, the insulation is sound, provided, of course, that all the other contacts are in proper condition. The method of making this test is shown in Fig. 42.

A third test known as the test for "earth" or leakage, may be made by means of the battery and galvanometer, and is often of service in locating leakage in cables. The method of carrying

out this test is as follows:—One of the wires from the battery is connected to the conductor to be tested, the other passes to the galvanometer, and from thence to earth, a rail or water pipe being the best place to make connection. Should there be leakage the needle of the galvanometer will be deflected.

In carrying out this test it is of importance to note that the test should be made over sections, and that these sections should be as short as possible, otherwise it may be difficult to locate the fault. The results of such tests vary with circumstances,

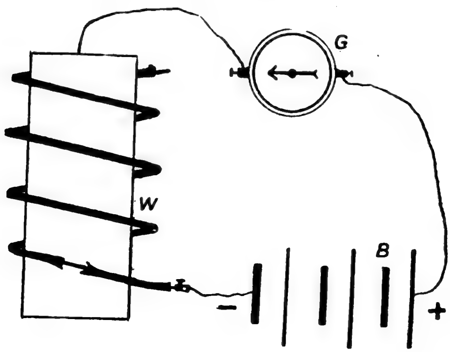


Fig. 42.—Insulation Test.

B = Battery. | G = Galvanometer.
W = Wire being tested.

and the person who carries them out must exercise common sense with respect to the various deflections indicated, before coming to a hasty conclusion regarding their cause.

The faults that occur during the working of dynamos, and which have already been alluded to, are:—

1. *Failure to excite.*
2. *Sparking at the brushes.*
3. *Excessive heating.*
4. *Vibration.*
5. *Variation of speed.*

These faults may be due to several causes, some of the more important of which will now be pointed out, and the method of dealing with them explained.

Failure to excite may be due to numerous causes, but it must be remembered that both compound and shunt-wound machines take some little time to build up their current, and a good few

minutes may pass from the time of starting until they are fully excited.

If, after a reasonable time, the machine fails to excite, then the cause must be ascertained, and will probably be found due to some of the following defects :—

(*a*) *Improper Connections.*—When the machine is first started failure may be due to the above, and must be remedied by connecting up in the correct way. The various diagrams of connections already given should serve to set this matter right.

(*b*) *Too Low Speed.*—With compound and shunt-wound machines a certain speed must be attained before they begin to excite. If after running a few minutes no current is produced, it is advisable to run up the speed, which can again be slowed down to the normal when the voltage rises to the desired height.

(*c*) *Brushes not on Neutral Points.*—If the brushes are not set in the proper positions the E.M.F. of the armature is not wholly utilised, and the machine may thus fail to excite. The brushes should be adjusted by means of the rocker to their correct position, as already pointed out. Should any doubts exist as to the correct position of the brushes, they can be moved from point to point by means of the brush rocker, until the correct position has been attained. Should such a course be necessary, some little time must be allowed between each shift, so as to give the machine time to build up current, which it will do when the brushes are finally moved into the proper positions.

(*d*) *Defective Contacts.*—If the contacts of the various connections are not kept scrupulously clean, the machine may fail to excite. This is very likely to take place if oil be allowed to find its way about the contacts, as oil acts as an insulator, and might readily interpose a resistance of sufficient magnitude to prevent the machine from exciting. The only remedy is to keep all contacts bright and clean, and completely free from oil and dirt of all kinds.

(*e*) *External Circuit Open.*—This would only affect a series-wound machine, and might be easily ascertained with the galvanometer, but it may be observed that the break in the circuit might be of such a nature that the galvanometer might give a deflection, while at the same time the very small current first generated by the machine might not be able to pass the break. After seeing that all contacts and switches are in place, and that the external circuit is all right, short circuiting the terminals may be resorted to in order to get the machine to excite. This operation should be performed with care, the best way being to fix a short piece of wire, with ends bared of insula-

tion, to one terminal. A longer piece of *insulated* flexible wire should be fixed to the other terminal. The bare end of this longer piece of wire is brought into momentary contact with the short piece projecting from the other terminal. Should the machine excite, the current will cause a spark between the two wires when contact is made or broken. Series-wound machines excite very rapidly, and for this reason care should be taken that the contact is of short duration.

(*f*) *Too heavy load* or short circuit in the external circuit. This fault is one that will prevent the excitation of a shunt-wound dynamo, because the whole of the current passes to the outside circuit, making the difference of potential between the shunt terminal almost zero. If the leads be taken out the dynamo will excite. Should this defect occur in a compound or series-wound dynamo, an overload is caused, which will blow the fuses.

(*g*) *Short Circuits in Dynamo.*—Should such occur in the terminals, brush-holders, field coils, or the armature or commutator, the dynamo may fail to excite. The terminals and brush-holders can readily be tested by means of the galvanometer, but, as a rule, when they are at fault it is due to metallic dust or other dirt collecting about them. When such is the case the remedy is obvious. When the short circuit is in the field coils the best test is to take their resistance by means of a Wheatstone bridge, a matter best carried out by a capable electrician. For faults of the armature and commutator, further details will be found in the part dealing with the armature.

Sparking at Brushes.—This defect is of frequent occurrence in most dynamos unless they are well looked after and kept thoroughly clean. In most cases the remedy is easily applied, but heavy sparking may be an indication of a more or less serious fault in the field magnet or armature circuits, and attendants should observe the class of sparking as it often gives an indication of the cause. Any of the following conditions will produce sparking, depending, to a greater or less extent, upon circumstances:—

(*a*) *Shifting of the Neutral Point.*—As already pointed out in Chapter II. (p. 27), when the various coils of the armature leave one pole and approach another, the current changes in direction. The position where this takes place is known as the neutral point, and it is this position upon which the brushes should rest. This neutral point is not constant in position, but varies with the load, magnetism, &c., and the brushes may have to be shifted accordingly, but in a well-designed dynamo running under moderate variations of load, the brushes once set should not require much attention.

(*b*) *Faulty Alignment of Brushes.*—The brushes may be so set as to be out of line with each other, this is easily remedied, as all that is required is to put the brushes diametrically opposite each other, usually two segments of the commutator are marked so as to render this easy.

(*c*) *The brushes may be dirty*, a very frequent cause of defect, especially with copper-gauze brushes. The dirt may be due to the use of a lubricator, on the commutator, or from accumulations of dust. The parts should be cleaned with scrupulous care, using some anti-grease solution, such as turpentine or soda.

(*d*) *Insufficient Bearing Surface of Brushes.*—The bearing surface of the brushes may be too small, or uneven, to properly perform their functions. If the latter is the case they should be

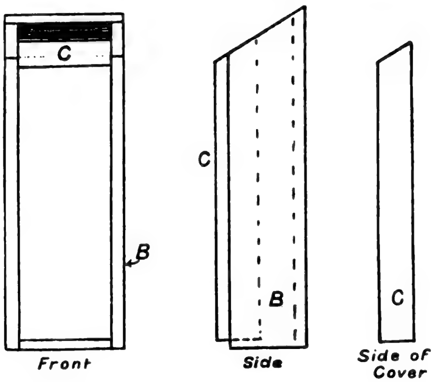


Fig. 43.—Trimming Box.
B = Box. | C = Cover.

trimmed. If it be necessary to keep the machine running while the brushes are being cleaned or trimmed, one brush may be removed at a time. In trimming, the brushes should not be put between the bare jaws of a vice, but should be held in a specially-constructed holder, the vice being used for holding this apparatus. The holder consists of a box with open ends and a movable top, one of the ends should be cut to the same angle as that to which the brush requires to be trimmed; this angle will of course vary with the width of the commutator bars, and would be different for different machines. The brush is placed in the box with its end projecting a little past the bevelled edge, the cover is placed over the brush, the whole gripped in the vice, and the brush carefully filed down to the requisite

shape and smoothness. The box may be constructed of either hard wood or metal, and its details are shown in Fig. 43.

(*e*) *The Dynamo may be Overloaded.*—The overloading may be due to short circuits in the external circuit, or an "earth" in the machine itself, or it may be due to a demand for power in excess of that for which the dynamo was designed. From whatever cause it may arise, it will show itself upon the voltmeter, or ammeter. Where a dynamo has to supply power to several motors, sparking is often caused by the fluctuating load (this is a special feature in coalcutting), and the brushes have to be adjusted to the point where least sparking occurs with what is considered the average load.

(*f*) *A Break Down of the Insulation* of either the dynamo or the external circuit may produce considerable leakage, which will not be indicated by the ammeter, but which can be tested for in the following manner:—Connect a piece of insulated wire to one of the terminals of the dynamo, and while the machine is running make short contacts with the earth. This is best done by means of the frame of the machine or some similar body having good earth connection. Should the insulation be faulty these contacts will be accompanied by sparking. To ascertain whether the fault is in the mains, or the dynamo itself, the former should be disconnected from the terminals and the test repeated as before. Should the spark still appear the fault is in the dynamo, if, however, no spark shows the fault has been in the external circuit, and in either case would have to be located as already described.

Excessive sparking at one brush usually betokens that a short circuit exists in one of the field coils. It will be indicated by the pole piece with the short-circuited coil being much weaker in magnetism than the others, or one of the coils will differ considerably in temperature from the others. This can easily be felt by laying the hand on them for a little. In series winding the cooler coil will be the faulty one, in shunt winding the reverse will be the case.

(*g*) *Faults in the Commutator* or a *Broken or Damaged Wire in the Armature Coils* may also lead to sparking. The commutator may be worn flat in some places or it may be short circuited in itself. The former fault is readily ascertained by raising the brushes and feeling the surface with the fingers while revolving slowly. The latter defect is often noted by the spark running round along with the cummutator as it were. When flats occur the best method of treatment is to put the armature and spindle in the lathe and turn up the surface of the cummutator anew. When doing this a sharp fine-pointed tool must be used and a

very fine cut taken. As soon as the flats are all out, fine emery cloth and an oily rag may be used to finish with. Great care should be taken in removing the armature from its bearings and drawing it out of the tunnel in which it works, as it is easily damaged; before putting it into the lathe it should be wrapped up in canvas or strong brown paper, so as to exclude dust and fine particles of the metal burnings.

The second fault mentioned above will be dealt with when dealing with faults in the armature.

Excessive Heating.—The forcing of current through the field and armature coils produces, in all machines, a certain amount of heat, and for this reason all dynamos will show an increase in temperature after running for some time. So long as this increase of temperature keeps under a certain limit (about 70° F. over that of the dynamo room, provided the room is well ventilated) no harm results, and good machines ought to run on full load for a period of at least six hours without the temperature increasing beyond this limit, after this there should be no further increase provided the load be kept constant. Should the rise of temperature be greater than this the insulation softens and ultimately gives way. Failure of the insulation due to this cause is indicated by the smell of melting rubber or shellac. Overloads, from whatever cause arising, are responsible for increase of temperature, as well as for short circuiting. If machines are fixed in a damp position and have to stand idle for any length of time they may get damp, and this may cause excessive heating. Such machines should, on starting, be run for some time under light loads which allows them to become dry.

Vibration.—Since in the dynamo the moving parts rotate only there should be little vibration, provided everything is in good condition. If vibration occurs to any extent, it will be due to some of the following defects:—Foundations bad, or machine insufficiently secured to them; badly jointed driving belt; side play upon armature shaft, or armature out of balance.

(*a*) The question of *foundations* has already been treated, and need not be further referred to. The bolts securing the machine should be examined from time to time to see that they are not becoming slack.

(*b*) *The belt* should be selected for the particular purpose to which it is applied, and ought to conform to the conditions already laid down regarding it.

(*c*) If the armature shaft has too much *side play* the result is that the shaft, or in some cases the driving pulley, knocks against the bearings. The remedy is to take up the play by

putting a washer of the requisite thickness between the shaft collar and the bearing.

(*d*) *When the speed of rotation is high*, as in the armature of a dynamo, it is important that the weight should be uniformly distributed round the shaft. This is, as a rule, well looked to by the makers of machines, but it sometimes happens that after the machine may have been badly overloaded, or where the binding wires have given way, the armature may get a little out of balance. This can be easily detected by supporting the shaft on two level knife edges; the heavier side, if such exists, will have a tendency to turn to the bottom. The remedy usually applied is drilling holes in the driving pulley at the heavier side, or if the construction of the pulley does not admit of this loading the lighter side with lead placed upon the inner side of the rim.

Variations of Speed.—This arises in many cases from circumstances which only cause temporary inconvenience, and which are easily set right, such as reduced speed of driving engine due to fall of steam pressure, &c. There are, however, other causes of a more serious nature, such as the overloading of the machine, slipping of the belt, or armature rubbing in tunnel.

(*a*) *Overloads* have already been dealt with under sparking.

(*b*) *Slipping of the Belt.*—While some little slip is permissible under the conditions of belt driving such slip should be reduced to a minimum by keeping the belts as tight as possible under the circumstances.

(*c*) Sometimes the windings get slack upon the armature and come in contact with the pole pieces, or it may be the binding wires touch while the armature is revolving. This is easily noticed by the noise produced, and may usually be remedied by putting on new binding wire, and, if necessary, increasing the number of bands, the windings having previously been beaten well into their place by means of a wood mallet.

The **Armature,** which is a most important part of the dynamo, now comes under consideration, the chief faults being short circuits and breaks or disconnections in the circuit.

(*a*) *Short Circuits.*—These may take place between the wires of the individual coils or between adjacent coils. They may also take place through the binding wires or through the armature core.

When a short circuit takes place between the wires of individual coils sparking at the commutator and a smell of burning shellac are the usual indications. The dynamo should be stopped at once, and the faulty coil will easily be detected by its temperature, as it will be much hotter than the others. It is

possible, however, that visible signs of the excessive heat are beginning to show.

When a short circuit takes place between the adjacent bars of a drum armature it usually results in a complete stoppage of the current. The method of detection is one that had better be dealt with by the trained electrician.

(*b*) *Breaks in the Armature Circuit.*—When this occurs it is accompanied by vicious sparking at the commutator, and can usually be distinguished from a short circuit by the lesser heating effect on the armature. The sparking takes place when the commutator bar connected to the faulty coil passes the brush, and these particular bars are soon affected to such an extent that the faulty coil is easily determined. When this failure occurs it is often caused by the armature connections breaking away from the commutator lug. The remedy is re-soldering or jointing the broken ends. Should it be necessary to keep the dynamo running a temporary repair may be made by soldering the adjacent commutator lugs at each end of the broken coil together without removing the coil, but the first opportunity would have to be taken to put in a new coil or thoroughly repair the damaged one.

Faults in the Commutator.—These usually result from the existence of some of the other defects already described, and are usually either *flats*, *short circuits*, or *knocked-in segments*.

The remedy for *flats* has already been dealt with, and consists of turning down the surface of the commutator in the lathe with a sharp tool.

Short circuits are, as a rule, due to metallic dust, dirt, or grease, the remedy being attention and careful cleaning.

The commutator may receive an accidental *knock*, and, as a result, have one or more of its segments driven below the level of the other. Should the commutator be much damaged the better plan is to rebuild it. If only one or two sections are thus lowered they can in some cases be brought back by gripping the lugs with a small vice and then using a lever to pull them back into position.

The foregoing faults are those that are most likely to occur in the working of dynamos, and to the inexperienced the list may appear so formidable as to call forth the suggestion that breakdowns cannot but be of frequent occurrence. In a well-constructed dynamo this is not, however, the case, and with ordinary conditions of running there is no class of machinery less liable to develop serious defects. One important feature that must not be overlooked is the necessity for absolute cleanliness, both with regard to the machine itself and also to

its surroundings; if this be duly observed it will save trouble on many occasions. Another important point is the necessity for the attendant to take an intelligent interest in the machine under his charge, and to endeavour to get a grasp of the principles of its action. The latter point could be aided to a great extent by competent men who, when called to do repairs might point out to the attendant why such repairs have been rendered necessary, and thus possibly prevent their occurrence a second time.

There is the further question of **coupling up dynamos** so as to work together on the same circuit. This is not often required about collieries meantime, and cannot be dealt with here. All information regarding the methods adopted will be found in text-books dealing with the subject of electrical engineering, and the reader is referred to some of those works if information on this subject is desired.

Engines.—In driving dynamos the choice of an engine will depend on several circumstances. The available steam pressure, the choice between condensing or non-condensing types, conditions of load upon engine, and method of connecting engine to dynamo will all need consideration. The engines may be of the ordinary horizontal slide-valve type, or they may be fitted with Corliss, Trip, or some other automatic expansion gear, as is usual about collieries. High-speed engines if used should be of the vertical type, either open or enclosed, and coupled direct to the dynamo.

A third class of engine that has been applied to this work is the steam turbine, that of Parson's design, being the best-known form.

For rough colliery work the ordinary horizontal slide-valve engine is largely employed, and answers as well as any other when the steam pressures available are under 60 lbs. per square inch. With higher steam pressures Corliss engines or those of that type give more economical results.

The power developed by any reciprocating engine is obtained as follows:—

$$\text{I.H.P.} = \frac{PLAN}{33{,}000}.$$

Where P = mean steam pressure in lbs. per square inch.
,, L = length of stroke in feet.
,, A = area of piston in square inches.
,, N = number of strokes per minute.

The above represents the work done in the engine cylinder and takes no account of frictional losses. The power that an

engine actually exerts while driving is known as the brake horse-power and is always less than the indicated horse-power under the same load. The brake horse-power varies from 75 per cent. of the indicated horse-power in small, to 90 per cent. in large engines, a fact which must not be lost sight of when estimating the power of the engine required. It must also be remembered that no dynamo gives out all the power imparted to it, but that only a portion of the total energy is converted into current, the remainder being lost in heating the armature and field windings, creating hysteresis and eddy currents and overcoming the friction of brushes and bearings. The actual amount of electrical energy obtained from a dynamo varies, but in good machines it should be about 90 per cent. of the mechanical energy imparted to the driving pulley.

The following example may serve to show how the foregoing statements can be applied:—

A dynamo has to give 100 electrical horse-power; its efficiency is 90 per cent. What will be the brake horse-power of the driving engine? If the engine has an efficiency of 80 per cent., what will its indicated horse-power be?

$$\text{Brake horse-power} = \frac{100 \times 10}{9} = 111 \cdot \dot{1}$$

$$\text{Indicated horse-power} = \frac{111 \times 100}{80} = 139 \text{ nearly.}$$

The size of the engine would depend on the mean steampressure and the piston speed. In ordinary horizontal engines it is not considered good practice to exceed a piston speed of 400 feet per minute, especially when the engine has to be kept running continuously.

If in the above example it be considered that the mean steam pressure is 40 lbs. per square inch, the engine has a stroke of 3 feet, and makes 65 revolutions per miuutc, what will the diameter of the cylinder be?

$$\text{Using the formula I.H.P.} = \frac{PLAN}{33{,}000},$$

$$\text{Then} \qquad 139 = \frac{40 \times 3' \times A \times 65 \times 2}{33{,}000}$$

$$\therefore \qquad A = 294 \cdot 03$$

$$\text{But diameter of cylinder} = \sqrt{\frac{\text{Area}}{\cdot 7854}} = \sqrt{\frac{294 \cdot 03}{\cdot 7854}} = \sqrt{374 \cdot 3}$$

$$= 19 \cdot 3'' \text{ (approx).}$$

The above result neglects the area of the piston-rod.

Parson's Turbine.—This form of driving engine has been applied to colliery installations, and forms an ideal drive. So far the number of places where it has been adopted are limited, but its working is being watched with great interest, and there

is little doubt that the next few years will see a rapid development of this system.

The parallel flow type, of which Fig. 44 is a section, is the form in general use.

It consists of a series of moving blades fitted upon a barrel, the diameter of which increases by steps at A, B, C on diagram. On the inside of the casing guide blades are fixed. Steam is admitted by means of a double-beat valve at A, and passes round to the end of the barrel at J. The guide blades are so constructed that the steam on entering is projected in a rotatory direction upon the succeeding ring of moving blades, imparting to them a rotatory force; it is then thrown back upon

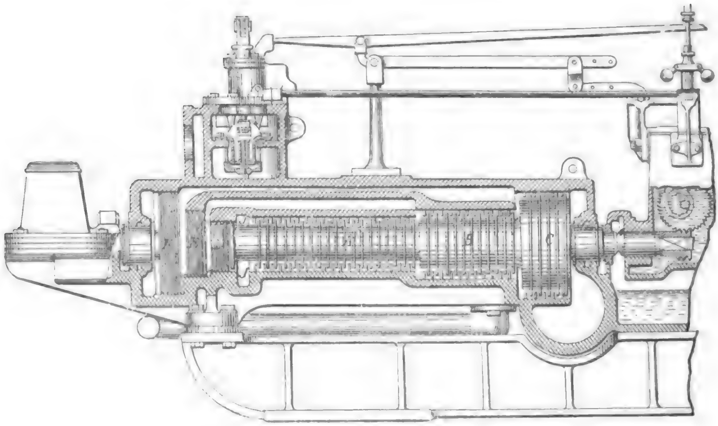


Fig. 44.—Parson's Steam Turbine.

the succeeding ring of guide blades, the reaction increasing the force of rotation.

The same action occurs at each of the successive rings, and is accompanied by a drop in pressure, and a gradual expansion of the steam. The parts marked D, E, F are not part of the energy receiving arrangement, but are dummies constructed for the purpose of taking up end thrust, but at the same time they form a practically steam-tight joint.

Steam is admitted to the turbine in a series of gusts by means of the double beat valve, H, the valve being operated by means of a relay in mechanical connection with the turbine shaft. When used for electrical work the duration of each gust of steam is controlled by means of a solenoid, connected as a shunt across the field magnets of the dynamo, and acting at the end of

a lever. The governing of the turbine is very exact, the throwing off or on of the full load producing a variation of speed of not more than 2 per cent.

For a given power the turbine occupies a very small floor space, and requires practically no other foundation than a block of wood placed level upon the floor. The economy is most marked; tests made by Professor Ewing of Cambridge give a steam consumption of 21·2 lbs. per electrical horse-power hour. Using a fair class of coal this corresponds to a consumption of about 2½ lbs. per hour; or, on comparison with an ordinary reciprocating engine, under 2 lbs. of coal per indicated horse-power per hour.

The turbine runs at a very high speed, and consequently the dynamo, which is coupled direct, is comparatively small for a considerable output.

At Ackton Hall Colliery, where six of these turbines are in use, the following outputs are realised:—

Three turbo-electric generators, each of the same type, furnish 300 amperes at 500 volts at 3000 revolutions per minute. One turbo-electric generator gives three-phase alternate currents of 400 amperes at 320 volts, the speed being about 2800 revolutions per minute, the exciter being carried on the same bed plate and driven by the same shaft. One small turbo-generator for lighting purposes gives 65 amperes at 110 volts, the speed being 9000 revolutions per minute; while another yields 400 amperes at 110 volts, with a speed of 4200 revolutions per minute. The above plant has been, and is doing good work throughout ever since its installation.

Whatever class of engine may be adopted it is of the utmost importance to see that the speed is efficiently regulated either by a mechanical or electrical governor, as, unless this is paid strict attention to, trouble is likely to result sooner or later. The greater the fluctuation of load the greater the necessity for attention to this detail.

EXAMPLES.

1. A dynamo has to furnish 80 E.H.P. Find B.H.P. of the driving engine if its efficiency is 90 per cent.—*Ans.* 88·8 B.H.P.

2. An engine driving a dynamo gives 100 B.H.P. What is the I.H.P. if the efficiency of the engine is 85 per cent.?—*Ans.* 118 I.H.P. nearly.

3. An engine has to develop 120 I.H.P. If steam be 60 lbs. per square inch, the length of stroke 3 feet, and the number of revolutions per minute 55, what is the diameter of cylinder?—*Ans.* 16 inches nearly.

4. What diameter of cylinder will develop 50 I.H.P. with a 4-foot stroke, 40 revolutions per minute, and steam pressure 30 lbs. per square inch (mean).—*Ans.* 14·8 inches diameter.

5. A dynamo has to supply 72 E.H.P., its efficiency is 90 per cent. What is the B.H.P. required to drive it? If the engine has an efficiency of 75 per cent., what will be its I.H.P.? If the piston speed be 360 feet per minute, and mean pressure of steam in the cylinder 50 lbs. per square inch, what will be the diameter of the cylinder?—*Ans.* 80 B.H.P.; 106·6 I.H.P.; diameter about 15¾ inches.

6. An engine has a cylinder 10 inches in diameter, with a 2-foot stroke. If mean steam pressure be 45 lbs. per square inch, and the engine makes 90 revolutions per minute, what would be its I.H.P.? If its efficiency be 80 per cent., what B.H.P. would it give?—*Ans.* 38·5 I.H.P. and 30·8 B.H.P.

CHAPTER IV.

MOTORS.

ELECTRICITY offers many advantages for the transmission of power over long distances, and has a great deal to recommend it for such purposes in and about mines. The ease with which cables can be carried from place to place and the economy, compared with any other system, are the principal factors in its favour. The question of economy of transmission, as will be seen from a perusal of Chapter I., depends largely upon the voltage employed, and the prevailing practice is to limit this to 500 for service in mines, and indeed many large colliery installations are fixed at less than this. Whether the highest voltage consistent with the conditions be used or not, there is no rival to the electrical system of transmission, if the power is required some distance away from the shaft bottom.

After developing the electric energy by the dynamo as already explained, the current is carried to the required place by means of the conducting cables, and there converted into mechanical energy by means of the motor. It will thus be seen that the function of the motor is exactly the opposite of that of the dynamo, for while the dynamo converts mechanical energy into electrical, the motor converts electrical energy into mechanical. In the former case, mechanical energy is expended in producing rotation of the armature in the magnetic field; in the latter case, this action is reversed. A current from a dynamo is passed through the coils of the armature and the field magnets, and the force of the magnetic field so produced, acts upon the coils carrying current in the armature and produces rotation. The force by which the armature is pulled round is called torque, and if a suitable connection be made between the armature shaft and the machinery it is desired to drive, this torque may be made to do work in proportion to its magnitude.

The construction of a motor is practically the same as a dynamo, and any well-designed dynamo will act as a motor, but for industrial purposes it is usual to build machines to work solely as motors, as they can be better adapted to fulfil the particular conditions applicable to the case.

When a motor is running by a supply of current from an outside source, the armature revolves in a magnetic field, and being, in point of fact, of exactly the same construction as the

one used in the dynamo, this rotation will tend to produce a current in a direction opposite to the driving current, and thus the driving current is dammed back. The tendency to produce current in the opposite direction, which is called the back E.M.F., becomes greater the higher the speed of the motor. At the moment of starting no back E.M.F. exists, and the current going through the armature is a maximum, as the speed increases the back E.M.F. increases until the quantity of current passing through the armature is a minimum. It is to this feature that the self-regulating properties and efficiency of working is due, as it allows the motor armature to take current in proportion to the work performed.

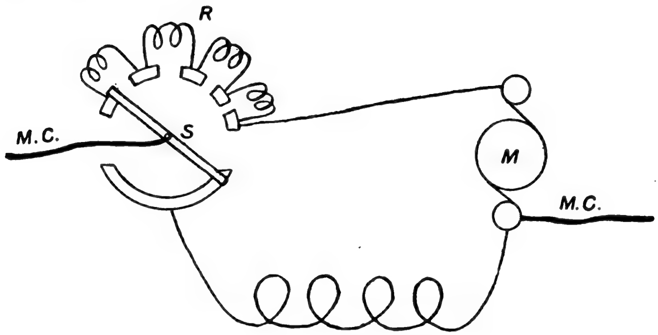


Fig. 45.—Starting Switch.

M = Motor. | S = Starting switch.
R = Resistance. | M C = Main circuit.

As already stated, there is no back E.M.F. in the circuit at the moment of starting, and currents of such magnitude may flow through the armature that its coils are damaged. To prevent this an extra resistance has to be introduced into the circuit until such times as the motor has got up speed, when it may be removed. For this purpose all ordinary motors are provided with a starting resistance.

These resistances vary in details of construction, but are the same in principle, and consist of coils of wire contained in fireproof boxes, or open where admissible, the wire being either of iron, German silver, platinoid manganin, or some suitable material, connected in series with the motor, and fitted with a switch for cutting out or putting in resistance at will.

A diagram of the arrangement of such a switch is shown in Fig. 45.

A starting switch of the above type has to be operated by the attendant, and may be left in such a position that damage to the motor may follow the switching on of the current by means of the main switch. The present tendency of electricians is to adopt automatic arrangements for the better protection of the motor where possible, and many forms of automatic starters have been devised. An automatic resistance for starting stationary motors is shown in Fig. 46. In this form the contact arm cannot be left on intermediate steps and is held at the "full-on" position by means of a magnet, which, on the stoppage of the current, releases the arm, which immediately flies back to the "off" position, throwing in all the resistance and opening

Fig. 46.—Automatic Starter.

the circuit. This movement is produced by means of a spring fitted in the boss of the contact lever. Another form of starter, known as an overload preventer and having an additional device for causing resistance to be inserted should an excessive current flow through the armature, is shown in Fig. 47.

This arrangement is one in which the coils of the electro-magnet on the one side are in series with the armature of the motor. A small armature is fitted to this electro-magnet and is capable of adjustment, so that, should more than a pre-arranged amount of current pass through the coils of the electro-magnet, the small armature is attracted and releases a detent which has

been holding the contact arm in position. Immediately the contact arm is released, it is thrown back by the spring into the "off" position, and the motor is stopped. These starting resistances are often called rheostats. The General Electric Company issue the following instructions for working their starters :—

To Start Motor.—"After closing the main switch, move the arm quickly on to the first large contact, hold it there two or three seconds, and move forward to the next contact, making each move quickly, and stopping the arm squarely on each

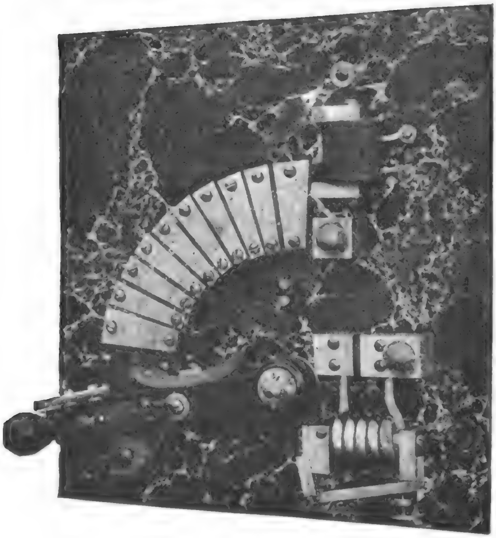


Fig. 47.—Overload Preventer.

contact plate. Give the motor two or three seconds at each step in which to speed up."

The motor should start on the first or second contact. If it does not, let the arm fly back and examine motor and circuits for trouble.

To Stop Motor.—"Do not touch the rheostat. Open the main switch. The rheostat arm will fly back when the motor stops."

Where motors are shunt- or compound-wound, the circuit should be closed through the shunt before the armature circuit is completed. Messrs. Siemens Brothers use the switch shown diagrammatically in Fig. 48 to effect this purpose.

The switch is so arranged that when the motor is started the switch arm comes into contact with a stud and puts the shunt coils of the motor and a resistance equal to the shunt coils in parallel. The next move breaks contact with the resistance, and leaves the field magnets fully excited by the current now being carried by the shunt coils. The next step closes the

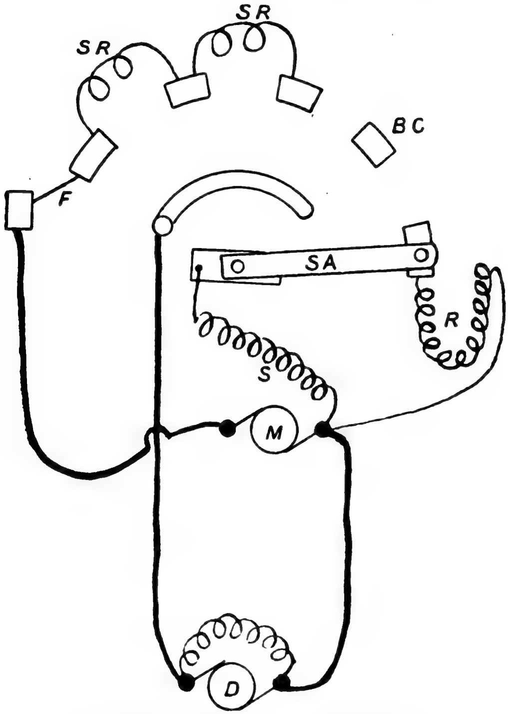


Fig. 48.—Siemens Starting Switch.

S R = Starting resistance.	D = Dynamo.	R = Resistance equal to shunt resistance.
B C = Blind contact.	S A = Switch arm.	F = Fuse.
M = Motor.	S = Shunt.	

armature circuit, at the same time putting in resistance, which is gradually cut out as the motor gets up speed. The motor must be stopped by means of the switch, and the operations already described take place in the reverse order. This switch performs a double function. In the first place, it completely

magnetises the field before the current is allowed to pass through the armature of the motor, which increases the ability of the motor to start with full load. In the second place, when stopping after first breaking the armature circuit and then placing a resistance in parallel to the shunt, it breaks the shunt coil circuit and places the shunt in series with an equivalent resistance. This has the effect of preventing the induced current produced by the breaking of the circuit of all large shunt-wound machines from damaging the insulation of the field magnet windings.

Another class of starting switch, which is used to a considerable extent in mining work, is that in which the current passes

Fig. 49.—Single Pole Liquid Switch.

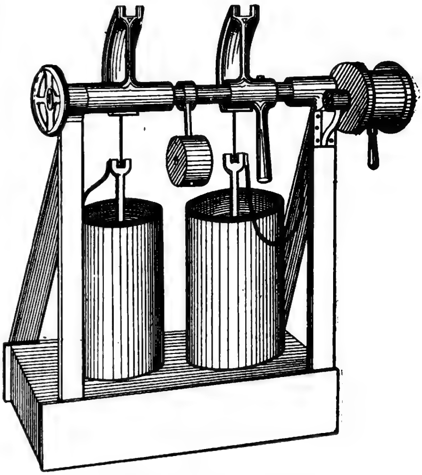


Fig. 50.—Double Pole Liquid Switch.

through a quantity of water, which is gradually diminished by lowering a lead cone from near the surface to the bottom of the vessel containing the liquid. By this means the amount of current allowed to pass to the motor is gradually increased as the distance between the contacts is decreased. This class of switch is made both as a single and as a double pole switch. Fig. 49 shows the single pole type, while the double pole is shown by Fig. 50.

There is no sparking with this form of switch, although it is open to the objection that, in some cases, it can be dropped too

quickly by a careless attendant. This can be obviated by fitting the switch with a dashpot filled with oil, so that the handle which is connected to it can only be moved slowly.

The motors of the continuous current type employed for mining purposes are of three classes, and are classified in the same way as dynamos by their windings, which may be either series, shunt, or compound, each type being suited to certain classes of work. The diagrams 25, 26, 27, already given, may be further consulted to show these systems of winding.

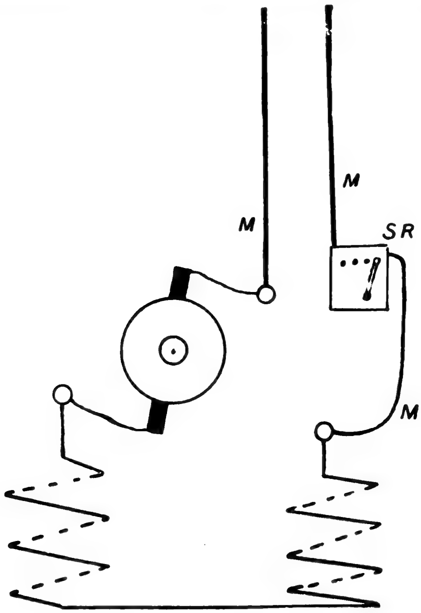


Fig. 51.—Connections for Series Motor.

M = Mains. | S R = Starting resistance.

Series Motor.—In this machine the field coils and the armature form one continuous circuit, and the current is the same in each. This condition allows the motor to exert a great starting torque, but if current is supplied at a constant pressure, the speed changes with any variation of the load. When the armature of such a motor is at rest there is no back E.M.F., and the whole admissible current flows through the armature and field coils, magnetising the fields to the utmost extent, and producing

the maximum torque or pull upon the armature. The rotation of the armature produces a back E.M.F., which gradually increases as the speed increases. This, of course, keeps back the current in the fields and armature, and a point is reached where the speed is constant for that particular condition of loading. Should the load be removed the motor races, the field is thus weakened, the back E.M.F. diminished, and a further increase of speed results, which may ultimately cause damage to the motor. For this reason a "series" motor can only be used where the load is constant, or under conditions where everything must be sacrificed for the sake of getting great starting power, as, for instance, in coal cutting. Should a "series" motor be overloaded the speed decreases, the torque is increased by the flow of more current through the armature and field magnets, and if the generator responds to the call for more current the motor will take it to such an extent that either a fuse blows or failure of the armature coils results from overheating. Motors of this type are made both bipolar and multipolar, and where conditions admit of their use the greatest economy as regards size of plant is obtained. The method of connecting a series motor to the mains supplying the current is shown in Fig. 51.

Shunt Motor.—In this type the field coils are connected as a shunt across the mains, and as a consequence the strength of the magnetic field produced is constant so long as the current supplied remains so. This has the effect of keeping the speed and the back E.M.F. nearly constant, even under considerable variations of load. The starting power is low, but can be much improved by first magnetising the field before closing the armature circuit, in the manner already described. This form of motor is well suited for, and is largely employed in, many classes of mining work, but must be of sufficient size to deal with the maximum load. Added to the fact, that to get the best results with this class of motor it must be of heavy construction, the first cost of plant would, for equal work, be higher than in the last case. The connections of a shunt motor to the supply mains is shown in Fig. 52. Like the series motor, a shunt motor may be either of the bipolar or multipolar type.

Compound Motors.—In this type the field magnets are wound with two set of coils, one being arranged as a shunt, the other in series, with the armature. The series coils, which are usually few in number, have the effect of increasing the magnetism of the field at starting and during times of heavy load. By this arrangement the speed is nearly constant under wide variations of load. This class of motor is used to a greater extent than

any other about collieries, combining, as it does, the chief features of both the series and shunt machines. A diagram of its connections to the supply mains is shown in Fig. 53. Like the others, both bipolar and multipolar types are in use. Where used in mines, motors may have current furnished to them either from lighting mains or from a separate circuit.

It is not advisable to use large motors served from a lighting circuit, and a motor so served should not be larger than about 10 horse-power. For motors of larger output a separate circuit should be provided, and in some cases it may be found an

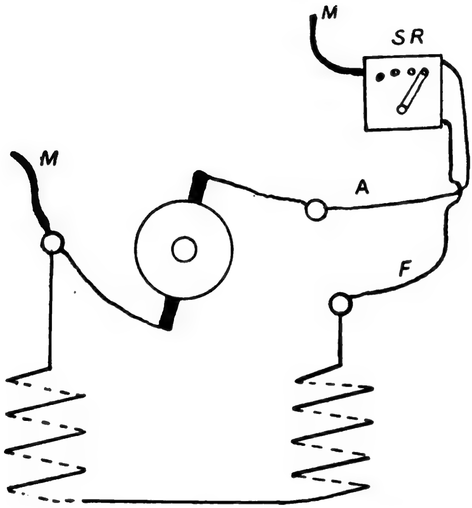


Fig. 52.—Connections for Shunt Motor.

M = Mains.	A = Armature connection.
S R = Starting resistance.	F = Field connection.

advantage to have a separate dynamo, in preference to driving several from the same generator. One generator running at nearly full load would be the more economical method, but advantages might follow the use of the other method, which would outweigh the consideration of an increased efficiency.

Electric motors when used in mines will in many cases require to be of the enclosed type, for several reasons. In the first place, unless the motor is enclosed, gas might be ignited by sparking; in the second place, it may be necessary to exclude damp; and in the third place, it may be necessary for their own

protection from falling material, and to exclude dust. When a motor is totally enclosed, the tendency to heat is great, and inspection is difficult. The author is of opinion that open machines might be used to a greater extent, if precautions be taken to keep the motor room free from gas, besides which there are many motors on the market which run sparkless, while there is the risk of covers being left loose or off altogether in the case of enclosed machines. In cases such as that of coal-cutting

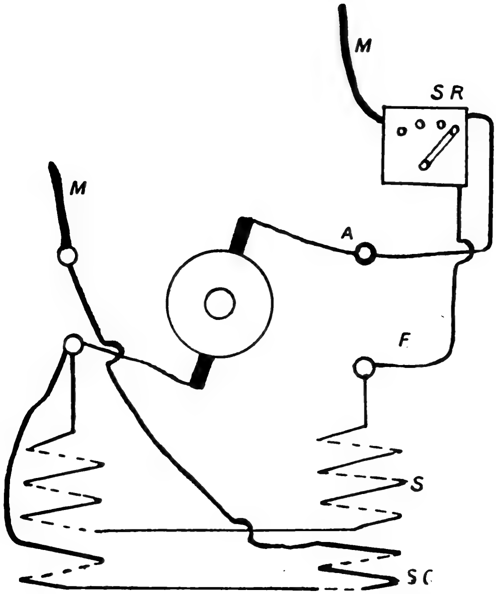


Fig. 53.—Connections for Compound Motor.

M = Mains.
S R = Starting resistance.
A = Armature connections.
F = Field connections.
S = Shunt coils.
S C = Series coils.

machines, where the risk from gas and also of damage to the motor is greatest, the latter may be protected with the usual covering, but holes, covered with strong wire gauze, should be left at convenient places, as this would still admit of some ventilation, and would help to keep down the temperature while running.

Much has been said regarding danger from gas, but it may be worth while noting that it requires a high temperature, and

consequently a fairly strong spark to cause its ignition. A further point is that the gas must be present to the extent of from 4 to 5 per cent. in the air before it will ignite at all, a condition very unlikely to obtain in places where motors have to be fixed. The danger is indeed quite disproportionate to the outcry that has been made. When motors are used in places where gas may at some time be present in dangerous quantities, they ought to be well looked to, kept in good running order, and be of such a size that overloading does not occur. If these precautions are observed, the danger is reduced to a minimum, and is certainly not greater than that existing from other causes in daily operation.

When a motor is employed to convert electrical energy into mechanical, not all the current supplied to it is *usefully* applied, part of it goes in heating the various parts of the motor, and in overcoming frictional resistances, the remainder only being available for mechanical work. The relationship between these two quantities is known as the efficiency of the motor, and, like that of all machines, it may be expressed thus—

$$\text{Efficiency} = \frac{\text{Work given out}}{\text{Work put in}} \cdot$$

It is possible to get very high efficiencies from electric motors provided they be made large enough, but in practice it is found that the cost is too great when the higher efficiencies are attempted. The following table gives the approximate efficiencies for various horse-powers, and the watts required at the terminals of the motors, at the efficiencies given, to produce one effective horse-power on the motor shaft :—

Effective H.P. of Motor.	Commercial Efficiency.	Watts per H.P. required at Terminals.
	Per cent.	
50 and upwards, ...	90	829
40 ,, ...	88	848
25 ,, ...	85	878
15 ,, ...	80	904
5 ,, ...	75	995
3 ,, ...	70	1066
1 ,, ...	65	1148
½ ,, ...	60	1244
¼ ,, ...	55	1357

Before the actual power required from the generator can be calculated the actual watts required at the motor terminals must

be known, and to this must be added the watts lost in the cables which convey the current from the generator to the motor.

As an example, let it be assumed that a motor of 50 effective horse-power with an efficiency of 90 per cent. has to be driven at a distance of 880 yards from the dynamo. The watts that the generating dynamo must furnish will be as follows :—

50 effective H.P. requires 829 watts per H.P. when efficiency is 90 per cent.

$\therefore$ Watts at motor terminals = 50 × 829 = 41450.

Suppose the voltage to be 400, then the amperes will be $\frac{4150}{400} = 103{\cdot}75$, say 104.

A reference to the table of carrying capacity of conductors, given in the first chapter, shows that a cable of 37/16 size will suit the purpose, its carrying capacity being 122 amperes and resistance ·3574 ohm per mile. The watts lost in this cable will be found by squaring the current passing in amperes and multiplying by the resistance in ohms, thus—

$$104 \times 104 \times 3574 = 3865{\cdot}63 \text{ watts lost per mile of cable.}$$

In this case the cable is exactly one mile in length, the distance from the dynamo to the motor and back ; the result may be summed thus—

Watts consumed by motor,	41,450
Watts lost in cables,	3,865·6
Total watts, =	45,315·6

This amount must be furnished by the generating dynamo.

The volts at the dynamo terminals will be got by dividing the total watts by the amperes, thus—

$$\frac{45{,}315{\cdot}6}{104} = 435{\cdot}7, \text{ say 436 volts, at dynamo.}$$

It will thus be seen that the loss in the cables amounts to about 9 per cent.

Suppose the dynamo which generates the current has an efficiency of 90 per cent., the effective or brake horse-power to drive dynamo would be

$$\text{B.H.P.} = \frac{45{,}315{\cdot}6 \times 100}{746 \times 90} = 67{\cdot}5 \text{ nearly.}$$

If the efficieney of the driving engine be taken as 85 per cent., then the indicated horse-power will be

$$\text{I.H.P.} = \frac{67{\cdot}5 \times 100}{85} = 79{\cdot}4,$$

and the efficiency of the combined plant will be

$$\text{Eff.} = \frac{50}{79{\cdot}4} = {\cdot}63, \text{ or 63 per cent.}$$

In running motors the precautions that have been already given regarding dynamos should be observed.

If motors of the open type are used in mines it is advisable to keep them covered when not at work with a damp-proof cloth, as the atmosphere in many mines is very humid, and dust is often abundant.

In some cases where motors are used their direction of running has to be reversed; when this is necessary the brushes should bear vertically on the commutator. A reversing switch is used, which is an appliance for changing the direction of the

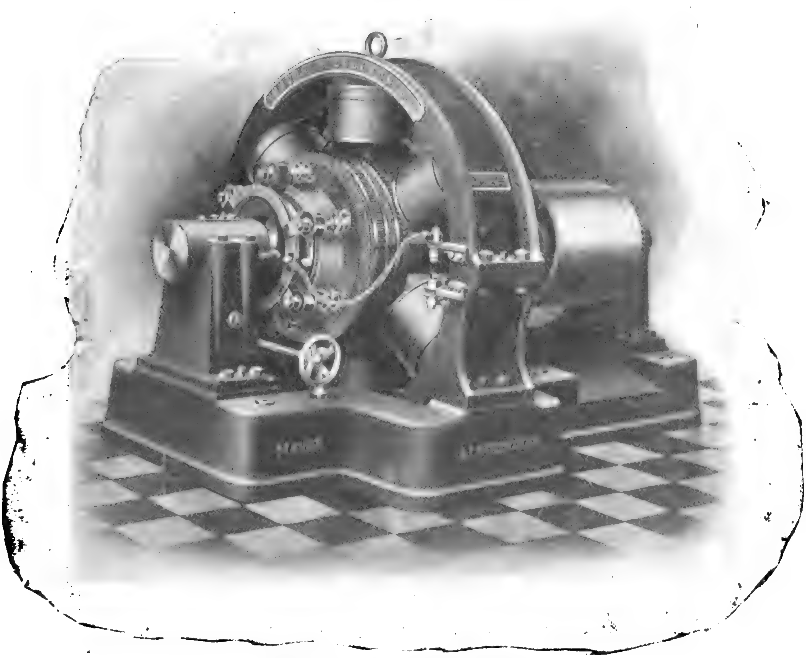


Fig. 54.—Multipolar Motor.

current in the field magnets of the motor, and is arranged as a part of the starting resistance in most cases.

From what has already been said it will be seen that motors resemble dynamos in their general features, and may belong to any of the types already dealt with under that head. Fig. 54 shows a multipolar three-bearing motor of a design well suited for heavy colliery work where the situation is favourable for an open machine.

Another multipolar motor, enclosed and coupled direct to a high-speed triplex pump, is shown in Fig. 55.

Motors of the multipolar type are largely employed in mines on account of the greater ease with which they can be made, enclosed or partially enclosed, besides which they are lighter for a given power.

Where opportunity admits motors should be run open; if totally enclosed a much larger motor will be required for the

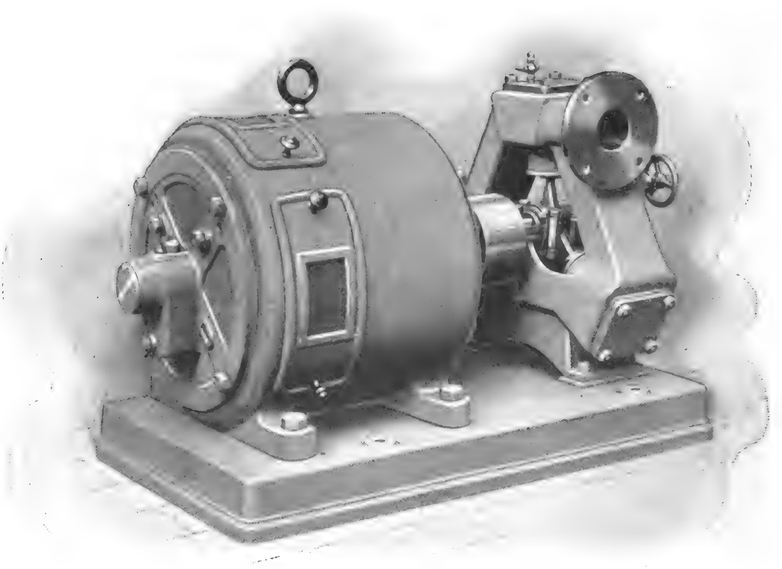


Fig. 55.—Enclosed Motor.

same work on account of the difficulty of getting the heat dissipated fast enough. In the case of one generator supplying current to one motor the machines are usually of the one pattern and size, so that a spare armature will fit either.

Alternate Current Motors.—This class of motor has been adopted to some considerable extent for mining purposes during the last year or two, and for this reason a short description of the type generally used will be desirable. The method of producing alternating currents has been dealt with already, and

it is for use with these currents that the above-mentioned motors are required. These motors may be divided into two classes :—

1. Synchronous.
2. Non-synchronous.

In the *synchronous* type the speed bears a constant relationship to the frequency of the driving current, and it cannot run at any other speed than its synchronous speed. Its greatest disadvantage is the inability to start until its speed synchronises with that of the generator; hence this form is little used in mining work, and may be dismissed without further notice.

The second form or *non-synchronous* motor is one where the speed varies to some extent with the load, and bears no relationship to the frequency of the supply. The motors of this type are self-starting, and can start under a considerable load. Special arrangements, which will be dealt with later, have to be made in the larger sizes to enable them to start when loaded.

These *induction motors*, as they are often called, as applied to mining, are either of the two-phase or polyphase type. With the two-phase motor four conducting cables are required, while with the other three conducting cables only are necessary; generally where such motors are installed they are of the three-phase class.

The motor consists of a primary circuit which is wound upon a fixed ring of metal, the windings being so arranged that the current, if two-phase, enters every other coil, or, if three-phase, each third coil in succession. This part, with its windings, corresponds to the fields of the continuous current machine, and is called the "Stator." Inside the primary circuit the movable part called the "Rotor" is placed. The rotor is built of laminated soft steel discs, which are held in position by being bolted to an open spider keyed to the motor shaft. The steel discs are slotted and fitted with copper conductors in each slot, the whole being bolted to a solid copper end ring.

This forms the secondary circuit and constitutes a sound mechanical contrivance, the copper bars being all short circuited render attention to insulation unimportant. The rotor of an induction motor corresponds to the armature of the continuous-current machine, and is built as described, whether the motor is two-phase or polyphase.

The current enters the windings of the stator, as already described, each coil of the set receiving current, which rises from zero to a maximum, decreasing again to zero, this process being repeated in the reverse direction. With two-phase currents the

second current starts from zero at the moment the first current has attained a maximum, passing through the same cycle of changes as the first, but always remaining one-quarter of a period behind.

With three-phase currents the second current starts when the first has passed through one-third of its cycle and the third current at a like point behind the second. All through the working this distance is maintained.

In the two-phase motor the current from the generator passes through two sets of windings, one current going to each set. As the first set of windings receives current an induced current is set up in the conductors of the rotor; this causes attraction between these conductors and the stator coils just in front, the rotor moving forward under the attracting force. As the rotor moves forward the current changes to the second set of windings producing similar conditions, and the rotor again moves forward. These changes are repeated so long as currents are delivered to the motor, and produce continuous rotation of the rotor as the result.

In the three-phase system the same conditions are set up, but currents are delivered to three separate sets of coils upon the stator, thus giving three separate pulls to the rotor instead of two.

Just as a back E.M.F., which varies with the speed of rotation, is produced in the continuous current motor, so an opposing pressure is induced in the conductors of the rotor. Should the motor be running and have its load increased the speed falls and the opposing pressure becomes less, thus causing an increase in the available driving pressure, or, in other words, increasing the torque. This produces an increase of current in the rotor and causes slip—that is, alters its speed relatively to the rotating field.

The alteration of the current in the rotor conductors reacts on the stator coils and reduces the strength of the magnetic field. This goes on until a point has been reached where the energy supplied to the motor is insufficient for the work to be performed, and unless the load is decreased the motor stops.

The induction motor thus differs in one important respect from the continuous current motor, as excess of load causes the former to come to a standstill, whereas with the latter, burning out of the armature coils would be the ultimate result.

It is usual to arrange that induction motors should take about 20 per cent. more than their normal working load before stoppage.

In large motors of the type under consideration the currents induced in the rotor when starting are of such magnitude that

their reaction weakens the stator field and renders the motor incapable of making a start. These currents are reduced by inserting a resistance into the rotor circuits at starting. This is done by two slip rings, which are insulated from each other and

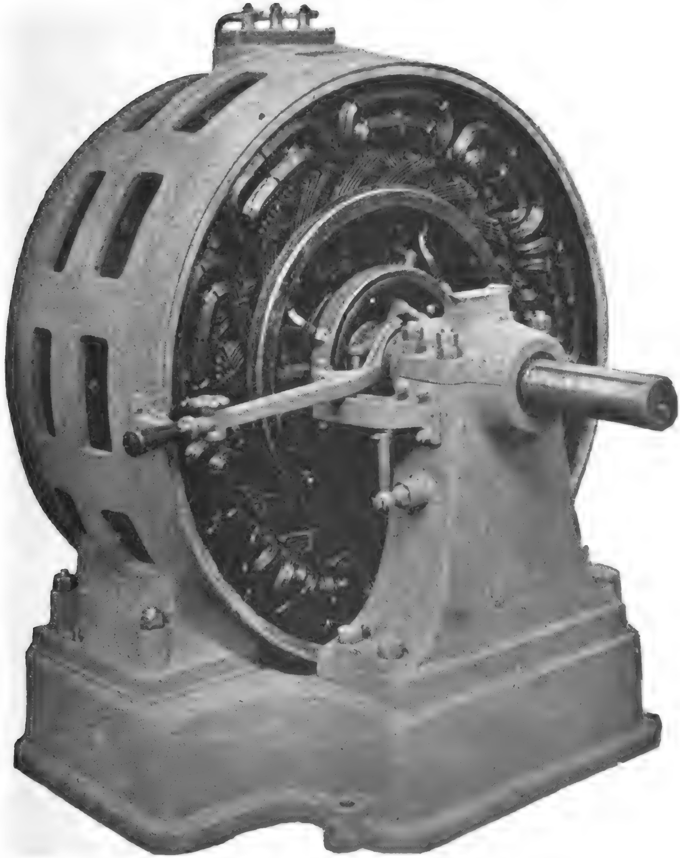


Fig. 56.—Three-phase Motor.

from the motor shaft and connected to the conductors of the rotor.

Brushes are fitted to these rings so as to make contact with them, the resistance being inserted between. The resistance is usually cut out of circuit by means of some automatic arrange-

ments as soon as the motor has got up speed. It is usual in mining motors of this type to cover in the slip rings, as—although this is a remote possibility—a spark might be produced at the contacts.

All motors of a size above 10 horse-power are, as a rule, fitted with this starting arrangement. A three-phase motor, with slip rings on rotor shaft, is shown in Fig. 56.

Various methods are employed for coupling-up the field connections, but the two most frequently adopted are known as the star method and the mesh method.

The *star method* is shown in Fig. 57, where the coils are cross

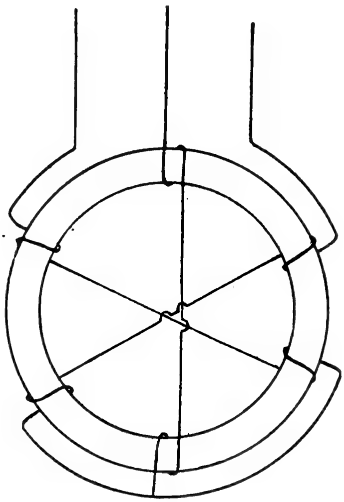


Fig. 57.—Star Connection.
W = Terminal connections.

connected in pairs, and jointed together at three of their terminals by the short piece of wire, W. The sum of the three currents being zero, the bunching together of the three wires does away with the necessity for a return.

The *mesh coupling* is shown in Fig. 58. Here the coils are jointed up in series, and the line wires connected to points between the coils. The fluctuation of the exciting power is greater in the mesh system than in the star, being, according to Mr. Kapp, 13 per cent. in the former and 7·25 per cent. in the latter.

The two-phase system requires four conducting cables to carry the current to the motor.

The efficiencies of the motors just described are very high, varying from 80 to 94 per cent. in the different sizes.

The system of transmitting power by three-phase currents is now being applied in some mines, its advocates urging the great advantage of freedom from danger due to sparking and high efficiency.

There is little doubt that where power is generated at a very long distance from the colliery the three-phase system is the most satisfactory. This condition, however, hardly ever occurs

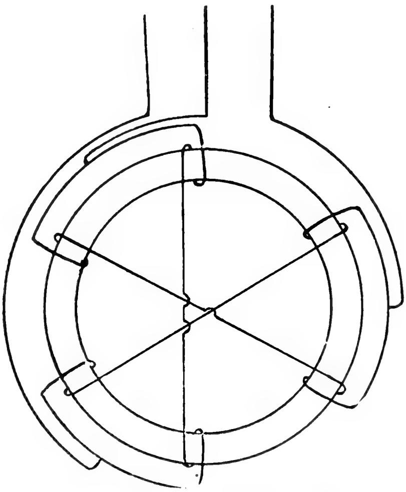


Fig. 58.—Mesh Connections.

at the present time, although it will, doubtless, be experienced when schemes for the general distribution of power over a number of colleries, each some distance from the central station, are put into practice. The greater efficiency of three-phase systems is due to the high voltage that can be used for transmission, and to the fact that high voltage alternating-current machines are much easier to construct than continuous-current machines to give similar pressures.

For the average conditions of colliery work the author is, however, of opinion that the continuous-current machine will still hold its ground, sparking at the commutator, as already shown, being chiefly a question of care, while the continuous

current has the further advantages of requiring fewer conducting cables and undergoing reduced line losses under moderate loads.

Changes from a continuous current to an alternating one and *vice versâ* can be effected by means of a rotary converter. This, with the question of transforming the current from high to low pressure or "stepping down," cannot be further entered upon here.

EXAMPLES.

1. A motor giving 20 effective H.P. is placed 600 yards away from the generating dynamo. The efficiency of the motor is 85 per cent., and the dynamo furnishes current at 420 volts pressure. What number of amperes would be required at the motor terminals, if 10 per cent. drop be allowed in voltage, and what size of cable would be required?—*Ans.* 45·3 amperes; cable, 7/13 size.

2. A motor of 80 effective H.P. has to drive pumps 1000 yards away from the generator. An engine and generator is supplied for this work only, the efficiencies of the motor being 90 per cent., and of the dynamo and engine 90 per cent. and 80 per cent. respectively. Allowing 10 per cent. for loss in cables, what will be the combined efficiency of the plant? —*Ans.* 58·4 per cent.

3. A motor has an output of 25 B.H.P., with a pressure of 300 volts at its terminals. It is situated 440 yards away from the generator. Taking its efficiency as 85 per cent., find (1) watts consumed by motor, (2) amperes required to feed motor, (3) size of cables to carry current, (4) watts lost in cable, (5) voltage at dynamo terminals, (6) B.H.P. required to drive dynamo.—*Ans.* (1) 21,950 watts, (2) 73·16 amperes, (3) 7/11 cables, (4) 1546 watts, (5) 322 volts, (6) 37 B.H.P.

4. If, in example 3, the efficiency of the engine driving the dynamo be 85 per cent., what will the I.H.P. be, and what will the efficiency of the plant be, taken as a whole?—*Ans.* 43·5 I.H.P.; total efficiency, 57·4 per cent.

5. A dynamo has to supply current to two motors, each of 20 H.P. and situated at a distance of half a mile. If the efficiency of the motors be 80 per cent., what H.P. must the generator furnish, if 10 per cent. be allowed for loss in mains?—*Ans.* 55·5 E.H.P.

6. If the dynamo referred to in question 5 has an efficiency of 90 per cent., and the driving engine an efficiency of 85 per cent., what is the I.H.P. of the engine? what is the combined efficiency of the plant?—*Ans.* 72·5 I.H.P., and 55 per cent. nearly.

CHAPTER V.

LIGHTING.

The use of electric light about collieries has received more attention than any other branch of electrical engineering, and has, for that reason, become better understood, current being oftener used for this purpose than for any other connected with collieries. It is safe to say that all collieries of any importance have found it to their advantage to generate current for lighting purposes, and no modern installation would now be considered complete, if it did not provide for lighting the surface at least, electrically.

The advantages to be gained are many, either compared with gas or what was perhaps more commonly used about collieries, oil lamps and open braziers burning coal, and colliery owners have not been slow in finding this out.

Some of these advantages may be stated as—

(1) Decreased cost.

(2) Better lighting.

(3) Less risk of fire.

(4) Freedom from fumes arising from lamps, &c.

(5) Absolute dependence upon light under all conditions of weather.

(6) Greater freedom from accidents due to imperfect lighting about sidings, &c.

(7) Saving of time in handling tubs, &c., due to better lighting.

(8) Lights can be fixed in positions where lighting with any other kind of illuminant would be impracticable.

The lighting is usually of what may be termed the combined type—incandescent lamps being used for all inside work and at places of minor importance upon the outside, while arc lights are used for lighting up sidings, yards, dirt-heaps, &c. The best form of dynamo to use when the lighting is carried out as above-mentioned is a compound-wound machine, as current is furnished in proportion to the demand. Should arc lighting alone be purposed, a series-wound dynamo would be the best machine to use if the lamps were run in series, but, should the lamps be run in parallel, the compound-wound machine would again be the most suitable. If accumulators be used, which is seldom desirable about a colliery, a shunt-wound dynamo is best adapted for charging them.

The ordinary incandescent lamp consists of a glass globe containing a carbon filament attached to two platinum wires, which form the terminals of the lamp. The air is exhausted from the globe, which is then sealed up. These lamps are made to give various candle-power (C.P.), with voltages running from 50 to 250. Lamps, the voltage of which is suited for that of the circuit, must be employed. Lamps of ordinary C.P. take about 3·75 watts per C.P. A 16-C.P. lamp at 100 volts takes about ·6 of an ampere, while a 200 volt 16-C.P. lamp takes about half this—namely, ·3 of an ampere, being in each case 3·75 watts per C.P. It will thus be seen that the C.P. of a lamp does not depend on the voltage, but upon the product of the voltage and the quantity of current passing through—that is, upon the watts consumed. The length of time that an incandescent lamp will last—called the life of the lamp—varies greatly, and may be taken on the average as from 800 to 1000 hours. Towards the end of its life the globe usually begins to blacken, owing to the disintegration of the carbon filament and the deposition of minute particles of carbon upon the lamp bulb. When a lamp reaches this stage—usually called the smashing point—it is best to have it replaced by a new one. An ordinary incandescent lamp may be run on a circuit where the pressure is slightly in excess of that of the lamp, say not more than 5 volts. When this is done, a large increase of light is obtained and the consumption per C.P. diminished; the life of the lamp is, however, greatly shortened. On the other hand, should the lamp be run on a circuit where the pressure is less than that which the lamp is designed for, by say 5 volts, a decreased C.P. results, with an increase of the life of the lamp and a decrease of its efficiency.

While the cost of power about a colliery is usually low it will in many cases be better to run the lamps slightly under their voltage; this requires more lamps to light a given space, but there ought to be a saving in cost of lamps owing to their increased life.

A number of foreign-made lamps are on the market; they are cheap but unreliable, and the use of good lamps, such as the Ediswan, the Robertson (Fig. 59), the Sunbeam, or other well-known high grade lamps, is much to be preferred.

As a general rule, the lighting circuits about a colliery are run in parallel (see Fig. 2), a constant pressure density being to be kept up between the mains, in modern installations averaging from 230 to 250 volts, the lamps being adapted to suit the particular voltage employed. Where very long circuits exist the application of the pressure at the middle of the circuit will

help to equalise the fall of potential. The arrangement of circuits is a matter best left to the engineer, as it requires some care and experience. It is, however, best to have the whole installation divided up into a number of small circuits; this allows for the easy detection of faults should they occur, such defects being less serious, as they only affect a few lights. The

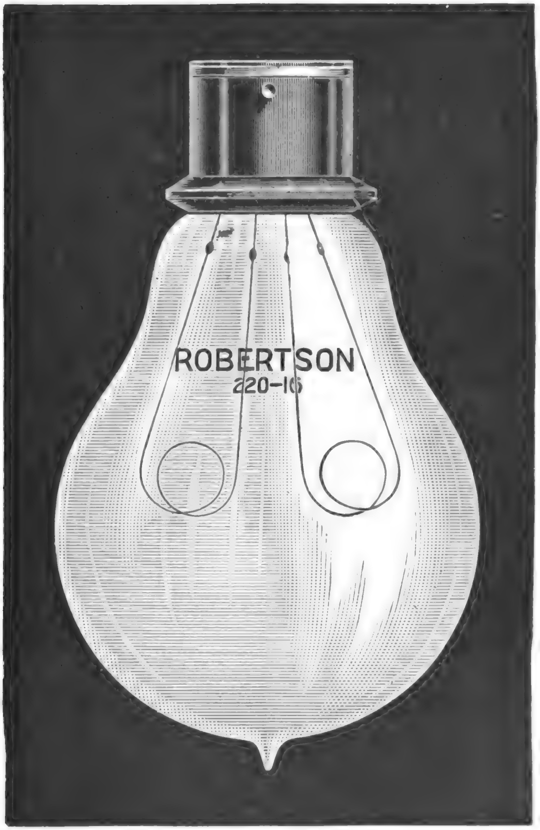


Fig. 59.—Incandescent Lamp.

current should be carried from the mains to a central distributing board, and from this small circuits taken to the various lamps. When a large amount of lighting has to be done circuits may be carried to branch distributing boards, and again sub-

divided. The details of such appliances can hardly be entered into here, but may be found in books dealing with this branch of electrical engineering. All circuits should be adequately protected by having fuses inserted in proper positions. The fuse consists of a short piece of wire which can only carry the working current safely.

Should the current in the circuit be increased abnormally from any cause this wire becomes overheated and melts, thus breaking the circuit. The fuse of the electric circuit thus bears the same relationship to the installation that the safety valve does to a boiler. Fuse wires are made of different metals and alloys, copper, tin, and lead being most frequently used. Tin and lead may be used up to about 50 amperes; after this the wire becomes large for single fuses, and a smaller copper wire may be substituted.

The following table (the authority being Sir W. H. Preece) gives the sizes of tin, lead, and copper wires that will fuse with currents up to 100 amperes. For larger currents an equivalent number of smaller wires may be twisted together to fulfil the required condition:—

Fusing Current. Amperes.	Tin Wire S.W.G. (Size). Approximate.	Lead Wire S.W.G. (Size). Approximate.	Copper Wire S.W.G. (Size). Approximate.
1	36	35	47
2	31	30	43
3	28	27	41
4	26	25	39
5	25	23	38
10	21	20	33
15	19	18	30
20	17	17	28
25	16	15	26
30	15	14	25
40	13·5	13	23
50	12·5	11·5	22
60	11	10	21
70	10	9·5	20
80	9·5	8·5	19
90	9	8	18·5
100	8·5	7	18

It must, of course, be observed that no circuit should be fitted with a fuse that just carries the working current, but a working margin has to be allowed. The allowable margin varies with circumstances, but not uncommonly a fuse to blow with twice

the working current is fixed in cases where the current is small, say, not over 20 amperes. With larger currents a less margin is allowed; for instance, a 70-ampere circuit might be fitted with a fuse which would give way at about 100 amperes.

As an example of dealing with currents which are greater than that found in the table, suppose a fuse has to be provided which will blow at 200 amperes. Then two No. 18 or four No. 22 copper wires would be twisted together to give the desired result.

The greatest care should be exercised in putting in suitable fuse wires, either in connection with lighting or the transmission of power, and a supply of such wire should always be kept at hand. The author has known cases where neglect of this precaution has caused considerable expense by unsuitable material being used to replace a burst fuse, and afterwards carrying current sufficient to burn out a motor armature. Until attendants are better schooled in the conditions attached to the successful management of electric plant, the only safe way to prevent such occurrences seems to be to have a quantity of suitable material always at hand, and to give strict injunctions that nothing else shall be used for replacing burst fuses.

Several methods are in use for running the cables, but for colliery work Simplex tubing will give as good and economical results as any. Where the cables have to be protected from damp screwed gas piping may be used with advantage. Wood casing is also used to a considerable extent, although, in the author's opinion, tubing is to be preferred. Where tubes are used they should be preserved by coating them with enamel from time to time. Lamps, either singly or in groups, according to circumstances, will be controlled by switches. These switches ought to be placed in convenient positions, such as close to the side of doors when the place has to be entered in the dark or in similar positions.

The functions of a switch are the opening or closing of a circuit when this is required. When such switches are placed on one lead only they are called single pole, and may be made to break the circuit at one or two places. If at one place only they are called single break, if at two places they are called double break. A double-pole switch is in reality two switches in combination, arranged so as to be worked with one handle.

Switches which are used for high pressure, or which have to carry large currents, are liable to give a vicious spark when contact is made or broken. To prevent this, or at least to modify it, the switch is made with two contacts giving a double break, and so dividing the spark, and thus preventing burning of the contact pieces.

It is of the utmost importance that all switches, for whatever purpose they may be used, should have bases which are formed of some non-combustible material, and should also be provided

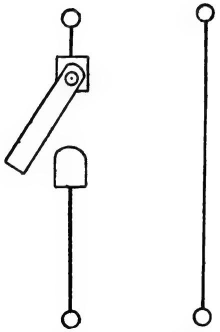


Fig. 60.—Single-pole Single-break Switch.

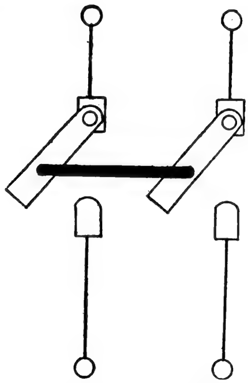


Fig. 61.—Double-pole Single-break Switch.

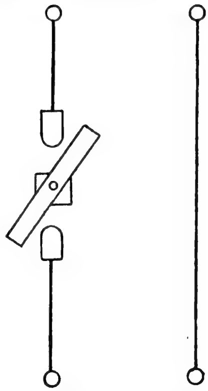


Fig. 62.—Single-pole Double-break Switch.

with a strong spring throw-off, so that no matter how the handle or lever is manipulated the switch cannot remain in an intermediate position, but must be either off or on. Slate is often

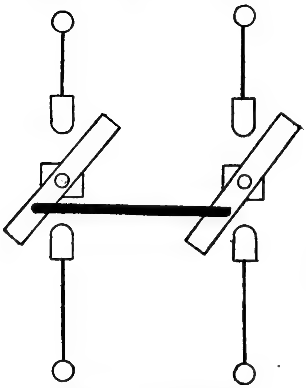


Fig. 63.—Double-pole Double-break Switch.

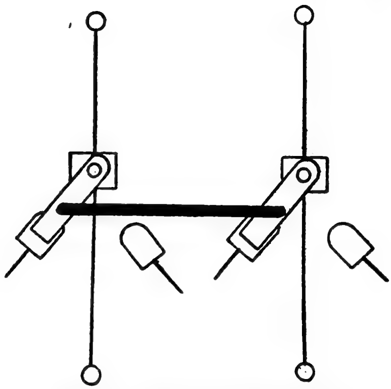


Fig. 64.—Double-pole Two-way Switch.

used as the material for the base, but should be selected so as to be free from iron, which occurs in many slates and which conducts current quite freely.

The connections of various types of switches to the mains can be shown by aid of diagrams. Thus Fig. 60 shows the connection of a single-pole single break, a class not often used. Fig. 61 shows a double-pole single break, and Fig. 62 a single-

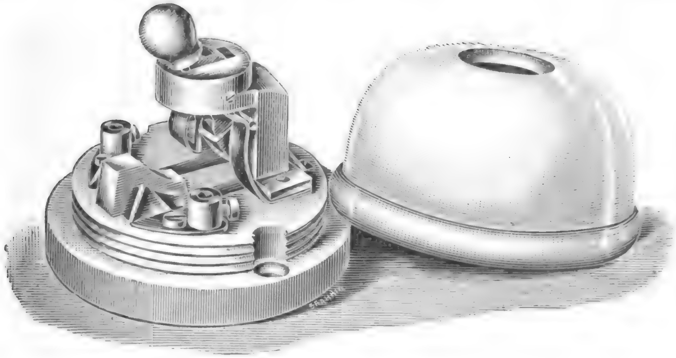


Fig. 65.—Switch.

pole double break; while Fig. 63 represents a double-pole double break.

It may be desired to direct the current into a different path,

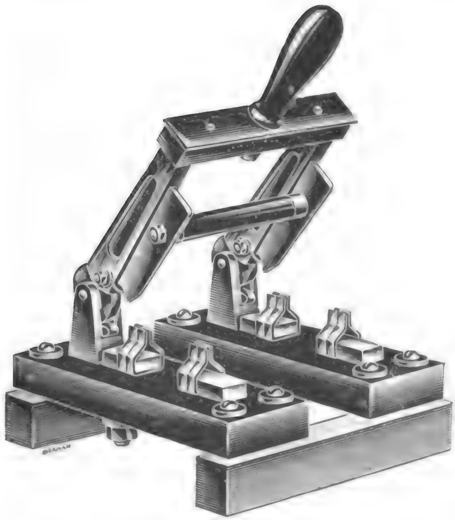


Fig. 66.—Double-pole Double-break Main Switch.

in which case it would be necessary to arrange a two-way switch. Fig. 64 is a diagrammatic representation of a double-pole two-way switch.

The number of good switches on the market is legion, and it would be quite impossible to discuss the merits of each; but Fig. 65 shows a form that is frequently adopted in connection with incandescent lighting. It is mounted on a porcelain base and fitted with a porcelain cover. The employment of porcelain instead of a metal cover lessens the risk of shock should the switch get slightly out of order.

For main switches, for lighting or power circuits, it is common to use those of the double-break double-pole type. Fig. 66 gives a general idea of the appearance of a switch of this form; while Fig. 67 shows a single-pole double-break switch.

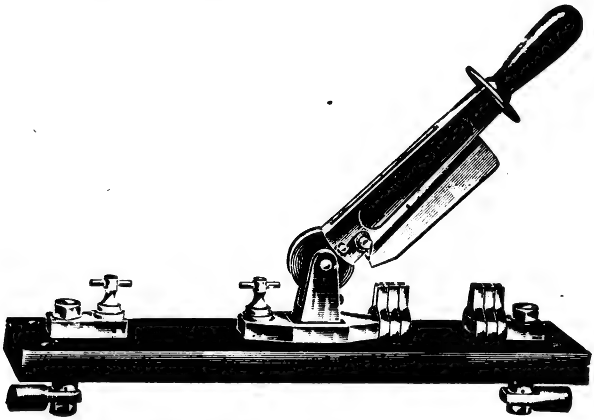


Fig. 67.—Single-pole Double-break Main Switch.

In fixing the position of the lights it will be necessary to consider what arrangements will yield the most efficient lighting with the smallest possible expenditure consistent with good work and material. The lamps may vary from 8 to 32 candle-power, depending upon the requirements of the place in which they are fixed; a good general rule to work on is to allow 3 candle-power for each 10 square feet of floor area provided the lamps can be placed to advantage, their best position being about 8 feet above the level of the floor. The inside walls of all buildings should be of a light colour, and in the case of pithead and screen sheds, &c., this could readily be obtained by white-washing at intervals. Recourse to some such method of keeping

walls more or less white renders lighting much more efficient, as white surfaces reflect from 50 to 70 per cent. of the light falling upon them; whereas if the surface is allowed to get dingy and black, which frequently occurs about collieries, the whole, or nearly the whole, of the light may be absorbed without reflexion.

The outside lighting of yards, sidings, &c., is, in most collieries, carried out by means of arc lamps. If the two ends of a circuit be brought together and then slightly separated the current will, provided its pressure is sufficient, leap across the gap thus formed. The continuous flow of the current under those conditions gives what is termed the electric arc. Should this arc be set up between two pencils or rods of carbon a brilliant white light is produced.

In order to keep the light constant the carbons must be kept constantly at the same distance apart—that is, some arrangement has to be provided by which the carbon is fed forward at a rate equal to its rate of consumption. This adjustment is performed by the arc lamp, of which a number of types are on the market.

Should the light be produced under such conditions that the atmosphere has free access to it the arc is classified as an open arc. In lamps of this class the consumption of the carbons depends upon conditions of current, class of current, &c., but may roughly be set down as about one inch per hour.

Should the arc be enclosed, so as to prevent the outside atmosphere from having free access to it, we have the type of lamp known as the enclosed arc lamp. In this class of lamp the carbons which burn in gases that are practically inert, chiefly nitrogen and carbon monoxide (the latter formed by the oxygen in the enclosed chamber entering into combination with the carbon upon the starting of the arc), are not consumed at the same rate, but last for a much longer time; a pair of carbons, measuring in all about 20 inches, burning from 60 to 150 hours.

The chief features of an arc lamp are:—

1. The carbons must be allowed to come together when the current is stopped.

2. A mechanism for drawing the carbons apart when the current commences to flow must be provided. This is usually called the striking mechanism.

3. A *feeding* mechanism must be provided for feeding forward the carbons as they burn away.

4. If lamps are to work in series with others, a short-circuiting cut out is necessary, so that the current can be carried past the lamp in the event of it being extinguished through the carbon becoming exhausted or otherwise.

Without going into a description of the various mechanisms adopted in the different lamps and their suitability for the particular purpose for which they are intended, the author would simply state that he prefers the enclosed arc lamp for colliery lighting, as the consumption of carbon is much less and the light is better distributed over a given area. The carbons used in these lamps must be of the very best quality and free from traces of metallic oxides, which, if present, stain the inner globe a deep brown, thus reducing the amount of light transmitted.

For a given energy consumption, the light emitted from an enclosed arc lamp is less than would be obtained from an open arc lamp under the same conditions, but the presence of the inner globe, which is usually of opal or alabaster glass, gives a much evener distribution of the light, which, at sight, would make it appear as if the enclosed arc were superior to the open arc, even in the amount of light produced. The efficiency of the enclosed arc is less than that of the open lamp, but the saving in carbon and trouble in renewal will, in most cases, do more than cover the slight difference in cost arising from this cause.

Other features of the enclosed arc are—that the arc is much longer, often about $\frac{1}{2}$ inch, and it requires a difference of pressure of about 80 volts at its terminals. The longer arc reduces the obstruction of the light in a downward direction, and the greater difference of voltage enables such lamps to be run across mains where the pressure is even over 100 volts. The risk of fire due to the escape of sparks from the arc is done away with in the enclosed arc by the use of the tight-fitting inside globe.

With open arcs, the difference of pressure required at the terminals varies from about 45 to 50 volts.

Whatever type of lamp is used, the current required will vary with the power of the lamp. Lamps taking from 5 to 30 amperes are in use, those most frequently used being 8 and 10 amperes for open, and 5 amperes for enclosed, lamps.

The arrangement of the lamps may be in series, in parallel, or in series-parallel. When the lamps are arranged in series, it is necessary for each lamp to be fitted with an automatic cut out, so that, in the case of failure of any one lamp, the current will short-circuit its terminals, which prevents such failure from affecting the other lamps upon the circuit. When the lamps are run in parallel, should the voltage be above that required at the lamp terminals, a resistance must be put in series with the lamps in order to keep the current at its proper intensity, and it should always be borne in mind that the use of a resistance simply wastes so much current by transforming it into heat.

Where resistances are used, it is best to have them well enclosed in fireproof cases.

In series-parallel, two or more lamps are joined in series and then put in parallel on the mains.

The number of lamps required to light a given area will depend very much on circumstances, but with 10-ampere open lamps, or 5-ampere enclosed, fixed at a height of about 20 feet,

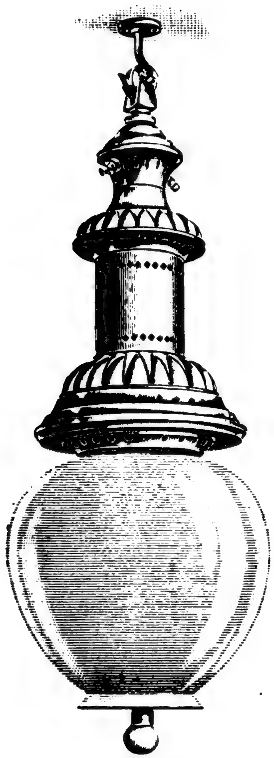


Fig. 68.—Jandus Arc Lamp.

Fig. 69.—Angold Enclosed Arc Lamp.

about 70 feet from lamp to lamp is a fair average for outside lighting. Obstruction of the light by buildings or anything of that kind may prevent any one lamp from giving what might, under more favourable conditions, be sufficient light; for this reason, the best available position for the lamps should always be studied.

For interior lighting, should arc lamps be selected, then 10-ampere open lamps or 5-ampere enclosed, at a height of 15 feet above the floor and fixed about 45 feet apart, give very good results.

In fixing the arc lamps, it is very important to see that they are suspended by an insulating ring or other non-conductor, and resistances should be fixed quite clear of all inflammable substances.

One of the best types of arc lamp is that known as the Jandus, of which Fig. 68 shows the general appearance. Although a non-focussing lamp, it possesses all the advantages of a focussing one owing to the slow rate of consumption of the negative carbon, and is in every respect well suited for lighting about collieries.

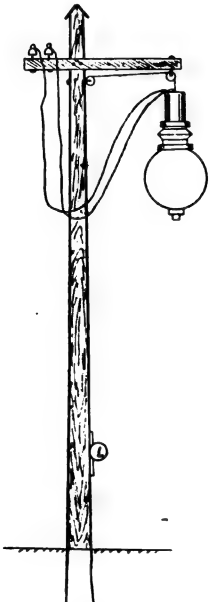


Fig. 70.
Arc Lamp Pole.

The "Angold" enclosed arc lamp is another lamp well suited for colliery requirements, and can be made to run in parallel with any voltage from 95 to 250, the standard consumption of current being 600 watts. The lamp burns from 100 to 110 hours when carbons of 11 mm. are used; with larger sizes of carbons it will burn longer, but the best light is obtained when the 11-millimetre size is used. Fig. 69 gives a general view of this lamp.

In most cases it is advisable to place arc lamps in such positions that the light from one illuminates the shadow areas of the other, as it must be borne in mind that strong light coming from a single source throws deep shadows.

When arc lamps are used about a colliery where only single shifts are being worked, they will not all be required during the greater part of the year, and as soon as the season comes round when their use can be dispensed with, they ought to be taken down and packed in a box or boxes with some suitable packing material, such as wood shavings, and stored in a dry place until again required. Leaving the lamps hanging out on the poles when not in use allows the damp to accumulate about the lamp and tends to its destruction.

The standards which support the lamps may be from 18 to

25 feet high with a cross arm attached from which the lamp is suspended. They require to be fitted with a small winch for raising and lowering the lamp when necessary. Ornamental standards are seldom used about collieries, and good straight larch or pine-wood poles are often employed. They ought always to be firmly fixed and have a metal cover on top to prevent rain soaking into the wood. The arrangement of an arc lamp upon such a pole is shown in Fig. 70.

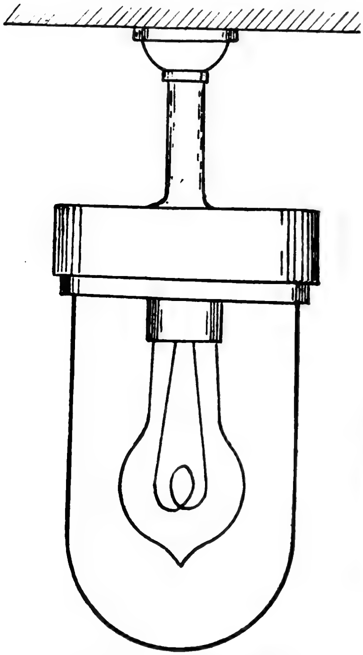


Fig. 71.—Roof Fitting.

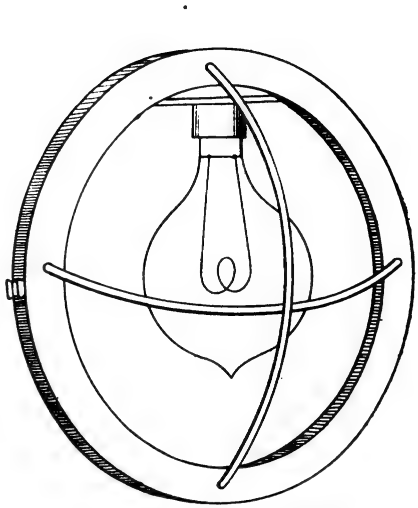


Fig. 72.—Side Light Fitting.

In addition to lighting the surface by means of electricity many collieries carry the current down the shafts to the pit bottom, and to important points upon the main haulage roads. The better light thus obtained at those points greatly facilitates the handling of large outputs.

With ordinary precautions no danger attends this system of lighting, and it might be adopted to a greater extent than it is.

Under such circumstances incandescent lamps are invariably used, their voltage being suited to that of the circuit, and

their candle-power, varying from 8 to 300, according to requirements.

These lamps may be fixed to the roof of the mine, or at the side, either close to the wall or projecting for some distance. Or they may be merely suspended and fitted with shades in the ordinary way, or enclosed in special fittings to protect them from injury. These fittings vary according to the position of the lamp. Fig. 71 shows a common form for fixing next the roof of the mine, while Fig. 72 shows a fitting well suited for a side light where little room exists, and the lamp has, on that

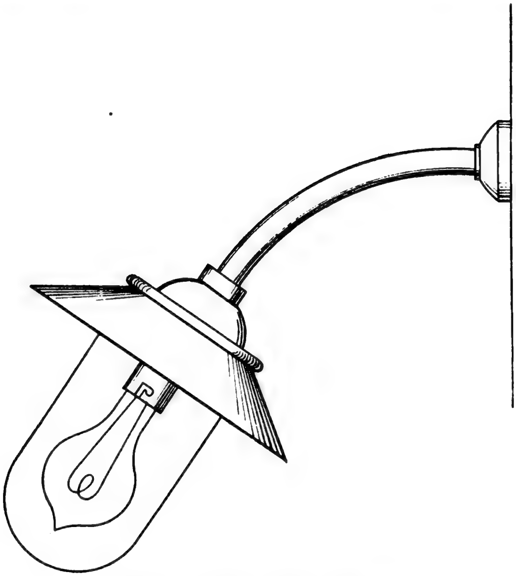


Fig. 73.—Side Light Fitting.

account, to be kept as close as possible to the side. Should there be sufficient room it is better that the lamp should stand out from the side a little, and a fitting suitable for this is shown in Fig. 73.

Another fitting very well adapted for exposed situations, either above or below ground, is shown in Fig. 74, where a shade is attached, and by this means the greater portion of the light reflected downwards. Here again great advantages will be derived by having the roof and sides of that portion of the mine which is thus lighted well whitewashed.

To generate the power required for lighting, it is best to have a separate dynamo, and to use it for this purpose alone. If circumstances make it necessary to take current for lighting from power circuits it will have to be observed that about 250 volts is the highest that any incandescent lamp will work successfully with, and if the current is at a higher voltage, the lamps must be run two or more in series. This is a usual method of lighting motor houses underground from the power supply main. Should the current be at 420 volts then two lamps of 210 volts each, run in series, would be necessary.

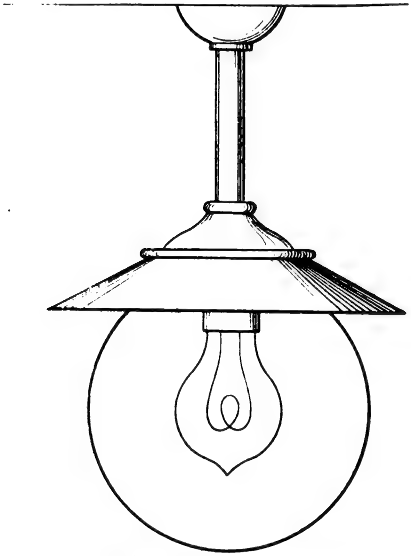


Fig. 74.—Roof Fitting with Shade.

Where two or more lamps are run thus, they can not be lighted separately, but must go on or off together.

Incandescent lamps have occasionally to be placed in situations where they are subjected to considerable vibration. Where this occurs lamps specially suited to withstand such vibration should be used. The Robertson traction lamp is well adapted to suit such circumstances, and can be obtained in two forms. In the ordinary type the filament is supported by suspending it from a glass bridge placed in the seal of the lamp (Fig. 75). Another and smaller form is shown in Fig. 76, where two short rigid filaments are placed in series. This

renders the lamp suitable for withstanding considerable vibration, and also for burning in positions where it has to be placed with the filament horizontal or oblique.

When much vibration is experienced the double filament lamp

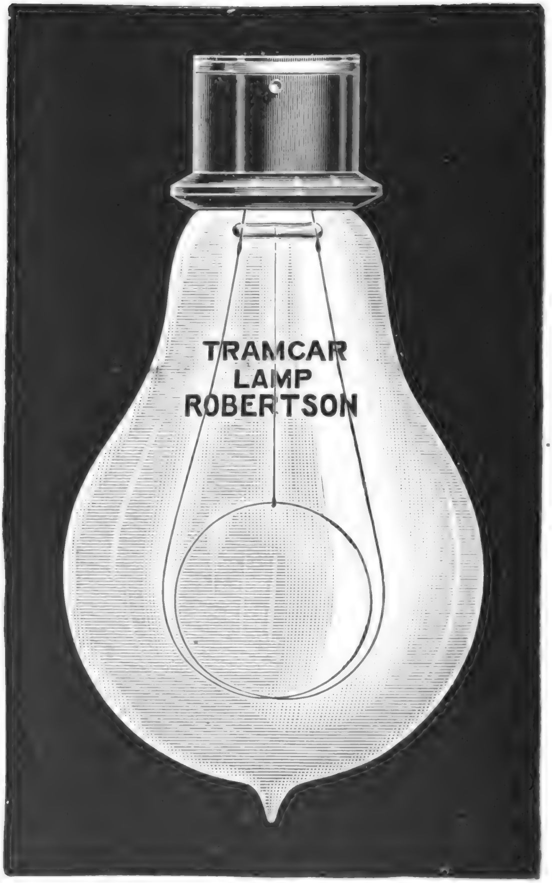


Fig. 75.—Robertson Traction Lamp.

is the better one to use, and is better fitted with loops than with the ordinary holder. This class of lamp is suited for such places as shaking screens, &c., where lamps with anchored filaments are of little or no use.

The power required for the purpose of lighting the various buildings and yards about a colliery now comes under consideration, and when looking to the requirements the colliery manager should not lose sight of possible future developments and extensions.

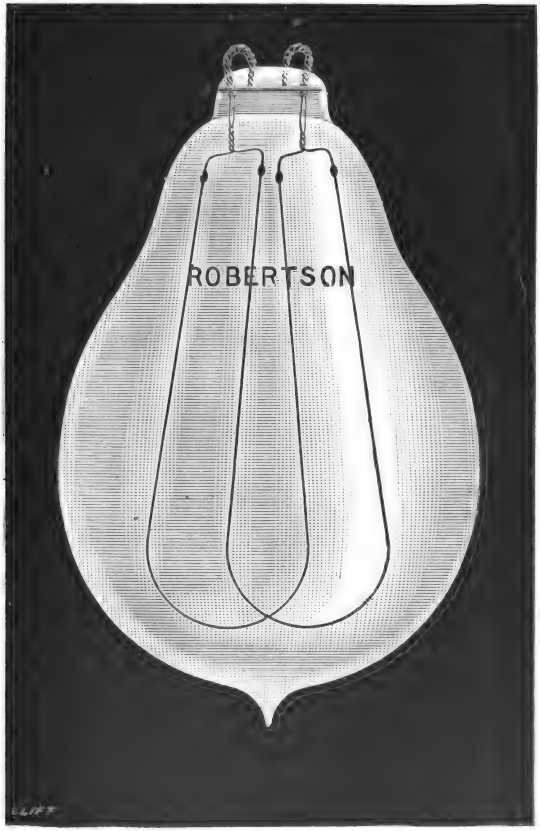


Fig. 76.—Double Filament Lamp.

With old collieries this may not be of much consequence, but in the case of new collieries it is of the utmost importance, as it is much better to have one large plant doing the work than a number of smaller ones, at least so far as economy in working is concerned. At one time it was thought necessary to duplicate

electric plant, but, with improvements in manufacture, there is now no more need for this course than for putting in duplicate steam engines.

The first thing to do is to decide upon the amount of light required, and the class of lamps to be used for producing it. After this has been done a simple calculation will give the power required to produce the light.

A rough way of putting it is to take twelve 16-C.P. incandescent lamps as equivalent to 1 H.P., and for arc lamps in parallel on a 110-volt circuit about

1 H.P. for one pair of 600 C.P. lamps.
$1\frac{1}{2}$ H.P. „ „ 1000 „
2 H.P. „ „ 1500 „

The exact method of calculation will be shown by the following examples :—

A dynamo is required to supply current to 150 16-C.P. lamps at 200 volts, and also to feed four enclosed arc lamps, each taking 5 amperes, at 100 volts, run two and two in series. What will be the required output of the dynamo (*a*) in kilowatts, and (*b*) in H.P.?

An incandescent 16-C.P. 200-volt lamp takes ·3 ampere.

$\therefore$ 200 × ·3 = 60 watts per lamp.
$\therefore$ 150 × 60 = 9000 watts for incandescent lamps.

For arc lighting we have four lamps, each taking 5 amperes at 100 volts.

$\therefore$ 5 × 100 = 500 watts per lamp.
500 × 4 = 2000 watts for arc lighting.
Total = 9000 + 2000 = 11,000.

$\therefore$ (*a*) Machine must have an output of 11 kilowatts, or (*b*) $\frac{11,000}{746}$ = 14·7 H.P.

The above is the actual output that the dynamo must provide, and the engine to drive it would require to give 14·7 B.H.P. in addition to what was necessary to overcome losses in the dynamo itself. An additional 15 per cent. added to the power should be sufficient for this size of dynamo.

$$\therefore \text{ Actual B.H.P. required} = \frac{14{\cdot}7 \times 100}{85} = 17{\cdot}3.$$

The above example takes no account of losses in the mains, which would necessarily need to be considered if the circuits were of any length.

The method of finding the loss in volts when a current of given magnitude flows along a given size of cable has been treated in Chapter I., and need not be again referred to.

As a further example, which also involves the consideration of the cable losses, we may take the following :—

Find the size of dynamo required to light the following circuits :—

(1) 100 16-C.P. 200-volt lamps, mains 200 yards long.
(2) 30 32-C.P. 200-volt lamps, mains 250 yards long.
(3) 6 arc lamps run two in series, each taking 5 amperes at 100 volts, mains 200 yards long.

Give the output of the dynamo in kilowatts, and find what B.H.P. would be required at the dynamo pulley if its efficiency was 90 per cent.

100 16-C.P. 200-volt lamps taking ·3 ampere each require 30 amperes.
30 32-C.P. 200-volt lamps taking ·6 ampere each require 18 amperes.
6 arc lamps taking 5 amperes each require 30 amperes.

We see that Nos. (1) and (3) circuits are each 200 yards long, and have to carry 30 amperes; referring to the table in Chapter I. we see that a 7/15 cable carries 29 amperes, which is the nearest to what is wanted, and that the resistance of this size of cable is 1·498 ohms per mile.

$$\therefore\ 1{\cdot}498 \times 29 \text{ amperes} = 43{\cdot}4 \text{ volts lost in 1 mile.}$$

By simple proportion we find the loss in 200 yards thus—

$$\frac{43{\cdot}4 \times 200}{1760} = 5 \text{ volts nearly.}$$

For No. (2) circuit, which is 250 yards long, and has to carry 18 amperes, we see, on referring to the table, that a 7/17 cable will carry 17·6 amperes, which is nearest to what is wanted; the resistance of this wire is 2·477 ohms per mile.

$$2{\cdot}47 \times 17{\cdot}6 \text{ amperes} = 43{\cdot}47 \text{ volts lost per mile.}$$

$$\therefore \text{ for 250 yards we have } \frac{250 \times 43{\cdot}4}{1760} = 6{\cdot}2 \text{ volts nearly.}$$

We thus see that the dynamo will require to give 206 volts at its terminals, and the total amperes is 30 + 18 + 30 = 78.

$$\therefore\ \text{Watts} = 78 \times 206 = 16{,}068.$$

The dynamo will therefore have to give an output of 16 kilowatts. This is 90 per cent., or $\frac{9}{10}$ of the energy that must be supplied to the dynamo pulley.

$$\therefore\ \frac{16{,}068 \times 10}{746 \times 9} = 24 \text{ B.H.P. nearly.}$$

The class of engine used to drive the lighting dynamo will depend upon the size of the lighting plant, and upon the available steam pressure. Where the pressure is over 90 lbs. per square inch and the plant of fair size, a compound engine will be the most economical. Where the plant is of very small size, or where the steam pressure is under 90 lbs., there is not much to be gained by compounding, and the extra capital involved would not be covered by the saving. In such a case an engine of the ordinary horizontal type, fitted with automatic expansion gear controlled by some high-class governor, by means of which just the required quantity of steam for the work to be done is

used, will be the more suitable engine. Should it be possible to condense the exhaust steam, compound engines may be economical even when the steam pressure is as low as 75 or 80 lbs. per square inch, but this will only be the case when the engines are running under a steady load. Should the load on the dynamo vary much, then compound engines may not be economical unless under much higher pressure—120 lbs. per square inch and upwards.

It sometimes happens that an old engine may be available about a colliery for driving the lighting plant. In such a case the engine should be fitted with a good governor, such as the "Pickering," so that its speed may readily respond to variations of the load.

Direct coupled fast-speed engines are used in some cases, but there is no doubt that a belt- or rope-driven plant gives more satisfactory results over a long continued period of working. When belts are used the joint should always be spliced flush, cemented, and sewn, as projections on the belt causes fluctuation of the speed, and consequently flickering of the light. For the same reason, engines must be fitted with a flywheel of sufficient weight to secure steady running.

EXAMPLES.

1. How many 50-C.P. lamps, each taking 3·5 volts per C.P., can be run off a dynamo giving 10 effective E.H.P.? Neglect loss in mains.—*Ans.* 42.

2. A dynamo is required to supply current to 300 16-C.P. lamps at 200 volts, and 8 enclosed arc lamps, each taking 5 amperes at 100 volts, run two and two in parallel series. What output must the dynamo furnish if 5 per cent. drop of volts be allowed for?—*Ans.* 23,157 watts, or about 31 effective E.H.P.

3. A dynamo running at a constant speed has to supply current for 200 16-C.P. 200-volt lamps, the mains being 600 yards long; and also 60 32-C.P. 200-volt lamps on another circuit where the mains are 700 yards long. What would be the voltage at the dynamo terminals? What size of cables would be used in each case? What effective E.H.P. would the dynamo require to supply?—*Ans.* 215 volts; cables, $\frac{7}{12}$ and $\frac{7}{14}$; 27·6 E.H.P.

4. A lamp circuit is supplied at a pressure of 100 volts. There are 42 lamps, all in parallel, and the hot resistance of each lamp is 150 ohms. How much current will the circuit take when all the lamps are on?—*Ans.* 28 amperes.

5. How many 16-C.P. lamps, taking 4 watts per candle, can be run off a dynamo giving 7 E.H.P.? Neglect losses in mains.—*Ans.* 81 lamps.

CHAPTER VI.

PUMPING.

In most mines water is given off from the strata, and has to be dealt with by means of pumping appliances of some kind. The amount of water encountered will vary greatly, but it may be taken as a rule that deep collieries are much less likely to have large quantities to deal with than shallow ones, the facilities for water draining into the workings from the surface being greater in the case of the latter.

Should circumstances render it possible to collect the water at the pit bottom, or an intermediate position in the shaft, then the pumping may be done by the steam engine direct, as this would, in most cases, be the more economical system. The only case where an electrical plant would compare favourably with such an arrangement would be where a large central generating plant was laid down and driven by the best and most economical engines procurable. Such an engine would probably give 1 H.P. for an hour with a consumpt of under 2 lbs. of coal. Allowing for 50 per cent. loss in the conversion of the mechanical into electrical energy, and *vice versâ*, 1 H.P. per hour would be obtained with under 4 lbs. of coal, which is much less than is required by many pumping engines. The same conditions hold with regard to all other operations requiring power about a colliery; many of the smaller engines, such as are used for driving screens, &c., being of types that have a coal consumption of 10 to 12 lbs. per H.P. per hour, and in some cases even more.

Should the water accumulate in dip workings at some distance from the shaft, and require pumps so placed that the power necessary to drive them has to be transmitted over a considerable distance, there is no system of transmission that can compare with electricity, and it is under such conditions that the greater number of electrically-driven pumps are at work.

Two conditions must be observed in the design of electrical pumps, which are of less importance in pumps driven otherwise —(1) The speed of the driving motor will be high. (2) To keep the driving motor running steady, it is necessary to have a nearly uniform resistance. To provide for the first, it is usual to make the pumps with a short stroke, so that an abnormally high

pumping speed is not reached, even when the pump makes a large number of strokes per minute. To secure the second condition, three-throw pumps are widely adopted, as they give an almost constant flow of water and require a very uniform turning moment to be exerted on their driving shafts. With such pumps, it is best to have the various parts independent of each other, so that in the case of failure of any one of the pumps, it could easily be disconnected and the others run while repairs were being carried out. Should the water to be pumped be of a corrosive nature, the rams, glands, and stuffing-box bushes may be made of gun-metal, as well as the valves and valve seats.

Since a motor of moderate dimensions revolves at a considerable speed, gearing of some kind must be used, or the pumps may be driven by belts. The usual practice is to have a combination of belt and spur gearing, the belt from the motor driving on to a counter shaft, which, in turn, is geared to the crank shaft driving the rams by spur gearing. Worm and worm-wheel gearing is sometimes used, but is not so satisfactory as belt or spur gearing.

The motor is, in some cases, connected to the pumps entirely by spur gearing, and in such cases the spur-wheel on the motor shaft is often made of raw hide and works into a wheel with accurately cut teeth. This reduces the risk involved in the use of toothed wheels when the speed is high.

Some manufacturers use helical teeth in all the gearing that is put upon their pumps. This adds to the cost of the pumps, but gives a very reliable gear.

At present, nearly all pumps which are intended for electrical driving are, where the water has to be forced against more than a few feet of head, of the two- or three-throw ram type. In cases where the head is low, centrifugal pumps coupled direct to the driving motor may be used with advantage.

In working pumps of the three-throw ram type, care should be taken to provide suitable conditions for the high speed and usually somewhat short stroke. High speed means that the water both in the suction and discharge pipes will flow at a high velocity unless the pipes are made of large area.

Should the suction pipes be of insufficient area, the water may encounter so much resistance to its flow that it is unable to follow the ram with the necessary speed, and a vacuum is formed behind the ram at the quickest part of the stroke, the water gaining on the ram at the end of the stroke and producing a considerable shock. In the same way, if the water in the discharge pipe has too great a velocity imparted to it, a

vacuum is formed at the point where the greatest resistance is encountered, and a similar shock is produced by the coming together of the two parts of the water-column, which have been slightly separated, in this way. Free admission of the water at the end of the suction is absolutely necessary, and pipes of such an area that the greatest velocity attained by the water is not more than 4 feet per second should be used in order to prevent such shocks. The use of an air vessel to regulate the flow and moderate the velocity is another necessary adjunct to pumps of this class.

The short stroke means that the receiving and discharge valves have to open and close a great many times in proportion to the capacity of the pump, as compared with one having a longer stroke. To get the best results, it becomes necessary to close the valves immediately the end of the stroke is reached, and to prevent water flowing back through them during the time of closing. To obtain such results and avoid loss, springs are used to press the valves back on their seats, or, as in the case of the Riedler pump, they may be closed mechanically. Should neither of these methods be adopted, care should be taken that the valve has no more than its proper lift, if the minimum of loss possible under the circumstances is aimed at. For this purpose, the area of passage should be kept constant; and, to do this, the valve must have a lift equal to one-fourth of the diameter of the valve seat.

To ascertain the quantity of water that a pump will deliver, the following calculation will be useful—

Let d = diameter of ram in inches.
L = length of stroke in feet.
N = number of effective strokes per minute.
S = pumping speed = L × N.
G = number of gallons raised per minute.

Then displacement per minute = $\frac{d^2 \times \cdot 7854 \times S}{144}$ cubic feet, and since 1 cubic foot contains $6\frac{1}{4}$ gallons—

$$G = \frac{d^2 \times \cdot 7854 \times S \times 6\cdot 25}{144}$$

$$= d^2 \times S \times \cdot 034$$

$$\therefore d = \sqrt{\frac{G}{\cdot 034 \times S}}$$

The above gives the theoretical result, but in practice an allowance has to be made for slip, this allowance being often spoken of as the coefficient of efficiency.

Thus, if the actual discharge is $\frac{4}{5}$ of the theoretical, $\frac{4}{5}$ is the coefficient. The coefficient of useful effect may be taken at about 85 per cent.

Taking this into account, the formula now becomes—

$$d = \frac{1}{\cdot 85} \sqrt{\frac{G}{\cdot 034 \times S}}$$

$$\text{or,} \quad d = 1 \cdot 176 \sqrt{\frac{G}{\cdot 034 \times S}}$$

The actual pumping speed for pumps of suitable construction for driving electrically may be from 30 to 150 feet per minute, the smaller sizes running at the higher speed, the larger running at the lower speed.

The motors used for driving pumps are usually of the compound type, as they will not run away should the pump lose its water. Enclosed motors are often used because of the damp situation of the pumps; it is better, however, to use open motors where the situation will admit, as less trouble is experienced with them. Shunt-wound motors have been used, but may cause trouble where enclosed, by the field resistance rising as the machine gets hot, and thus increasing the speed and the armature current. The addition of a few turns of series winding to such a motor would do away with any difficulty of this kind.

The following particulars regarding one or two pumping plants have kindly been furnished by Messrs. Scott & Mountain. The pumping installation at Milnwood Colliery, Bellshill, N.B., consists of a Tyne shunt-wound dynamo, constructed to give an output of 350 volts and 34 amperes. The machine is fitted with a sliding bed plate enabling the slack of the belt to be taken up while the dynamo is running. The current from the dynamo is taken to a double-pole main switch, and is then conveyed by an overhead cable of 2600 yards length to the pumps, which are placed in a pump house by the river.

The pumps are of the three-throw ram type, the rams being 6-inch diameter with 9-inch stroke, and are capable of delivering 120 gallons of water per minute when running at a speed of 40 strokes per minute.

The three-pump bodies are separate castings, each similar in design and interchangeable; each pump is fitted with a gland bushed with gun-metal, and the stuffing boxes are also bushed with the same material. Suction and delivery boxes are all made as separate castings fitted with gun-metal valves and seats, the valves being of extra large diameter to ensure an easy passage for the water, and each valve being fitted with an adjusting gear so that the lift can be regulated.

The connecting pipes both on the delivery and suction side are also separate castings, and an air vessel is fitted on the delivery branch. The object in constructing the pumps in this manner is to prevent any possibility of a total breakdown. Fig. 77 shows these pumps.

The rams are of gun-metal and are attached to slipper guides working in guide plates forming an oil-bath, and thus providing continuous lubrication.

The connecting-rods, crank shaft, and counter shaft are of steel, all fitted wih extra long bearings to avoid wear and tear.

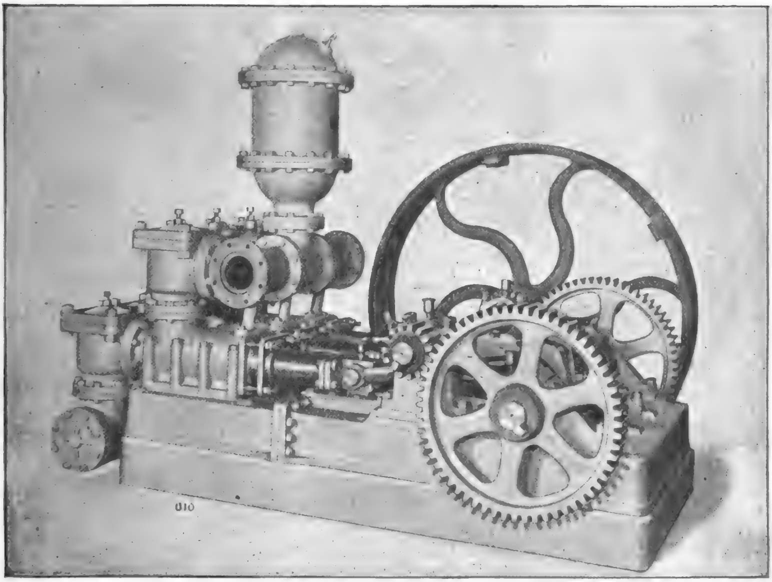


Fig. 77.—Milnwood Pumps.

The power from the motor is transmitted to the pumps through a pair of spur wheels, a pulley being mounted on the outer end of the counter shaft to receive the driving belt from the motor.

The motor is capable of giving 13 effective H.P. at a speed of about 700 revolutions per minute. The machine is mounted upon a cast-iron sliding bed plate, so that the slack of the belt can be taken up while the motor is running.

A starting switch is provided, so that the motor can be stopped or started slowly, and all shock taken off the pumps.

This plant has been at work for several years and has given every satisfaction.

What is perhaps the largest pumping plant in existence has been laid down at Arniston Colliery near Edinburgh.

The generating plant consists of two compound long stroke Robey engines, the diameter of the high-pressure cylinder being $16\frac{3}{4}$ inches and that of the low-pressure $26\frac{1}{2}$ inches. The length of the stroke is about 3 feet, and they run about 84 revolutions per minute. Each engine is capable of giving 350 I.H.P. with 120 lbs. steam pressure when working condensing, and is fitted with Richardson & Rowland's automatic trip-expansion gear.

The flywheels are each 15 feet diameter and grooved for nine cotton-driving ropes, each rope being $1\frac{3}{4}$ inches in diameter. The engines are fitted with barring gear for starting, and also with continuous lubricating gear throughout.

There are two dynamos fitted with drum-bar armatures, each dynamo being constructed to give 363 amperes at a pressure of 550 volts while running about 400 revolutions per minute. The dynamos are of massive construction, and are designed for continuous running.

The field magnets are of steel of high magnetic permeability and are made in three blocks, so that the magnet bobbins, which are placed above the armature, can be readily removed if required. The magnets are shunt wound, and a resistance is provided for the shunt, so that the E.M.F. can be regulated when necessary.

The armature shaft is made in two lengths, one part carrying the pulley, running in two bearings, and fitted with coupling to which the shaft supporting the armature is bolted. This arrangement enables the armature to be removed without disturbing driving ropes or pulleys.

The bearings are adjustable, fitted with bored and turned brasses, and lined with white metal, each bearing being continuously lubricated by means of an oil ring.

The main switchboard is designed so that either dynamo can feed the whole of the circuits, or if required the two dynamos can feed together on to the main circuits, or, as an alternative, the installation can be divided into halves, and either dynamo feed either half.

The main switchboard consists of an enamelled slate base fitted into a strong oak frame, and is mounted with two ampere meters each to read to 400 amperes, two volt meters each to read to 600 volts, and two recording ampere meters, so that the output of each dynamo can be recorded over a given period; two

double-pole main switches with double-pole fuses, and two special lever switches with sliding contacts to obtain the interchangeability already mentioned.

The current from the main switchboard is taken to a distributing board at the pit bottom by four cables each 400 yards in length. This cable is composed of 37 wires, No. 11 S.W.G., and is heavily insulated with vulcanised india-rubber, and armoured over all with steel tape. The object in having four cables is to enable the installation to be divided, under ordinary circumstances, into two circuits, and, if required, to allow of all being coupled together, or in the event of an accident to any one cable the remaining ones being connected up, so that the pumps can still be run.

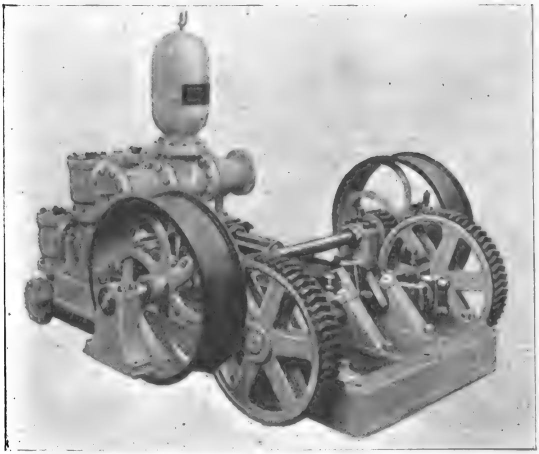


Fig. 78.—Arniston High-lift Pumps.

The current from the distributing board at the pit bottom is conveyed to one 500-gallon pump by two lengths of cable each 1130 yards long, or a total of 2260 yards composed of 37 wires, No. 12 S.W.G., insulated with vulcanised india-rubber, and securely cleated to the props along the main road.

Another branch is taken from the main distributing board to the four 100-gallon pumps, these cables are composed of 19 wires, No. 13 S.W.G. This cable is also insulated with vulcanised india-rubber. Other branches are taken to the various pumps from the main cables.

The pumps consist of one set of the three-throw type, fitted with 11-inch rams with 18-inch stroke, situate at the Gore pit bottom, to deliver 500 gallons per minute against a head of 678 feet; these pumps run at a speed of, approximately, 30 revolutions per minute (Fig. 78).

One set of pumps similar to the above at the Emily pit bottom is fitted to deliver 500 gallons per minute against a head of 256 feet through 3175 feet of cast-iron pipe. Both of the above pumps deliver through pipes 10 inches diameter, tested by hydraulic pressure to between 400 and 500 lbs. per square inch.

Three sets of pumps have been installed to the dip, each set being capable of delivering 100 gallons per minute against a head of 450 feet. These pumps deliver through 1200 feet of pipes 6 inches diameter.

The whole of the above pumps are of Scott & Mountain's improved mining type, and are fitted with gun-metal rams, interchangeable pump barrels, and valve boxes, suction and delivery pipes, branch pipes, and air vessels.

The pumps are fitted with outside slipper guides and adjustable crossheads, together with steel connecting-rods, forged steel crank shafts running in four bearings, and driving wheels and pulleys.

The large pumps are fitted with double driving wheels and pulleys, each set of gear being of sufficient size to transmit the power.

For driving the high-lift pump, which delivers 500 gallons per minute against a 678-feet head, two 80-H.P. electric motors are provided, the speed being about 450 revolutions per minute.

These motors are coupled together (Fig. 79), and are constructed so that the armatures will be interchangeable with the single 80 H.P. motor of the low-lift pump. The second set of pumps are driven by a single motor of 80 H.P., which also runs about 450 revolutions per minute.

The power from the motors to the pumps is transmitted in each case by driving belts. The two large pumps are driven by double belts each 15 inches wide, and the three smaller sets by belts 8 inches wide.

Each of the motors is fitted with a liquid starting switch, which enables the motors to be started without shock, and allows of the speed being regulated as required.

The general position of the various pumps is shown in the accompanying sketch (Fig. 80).

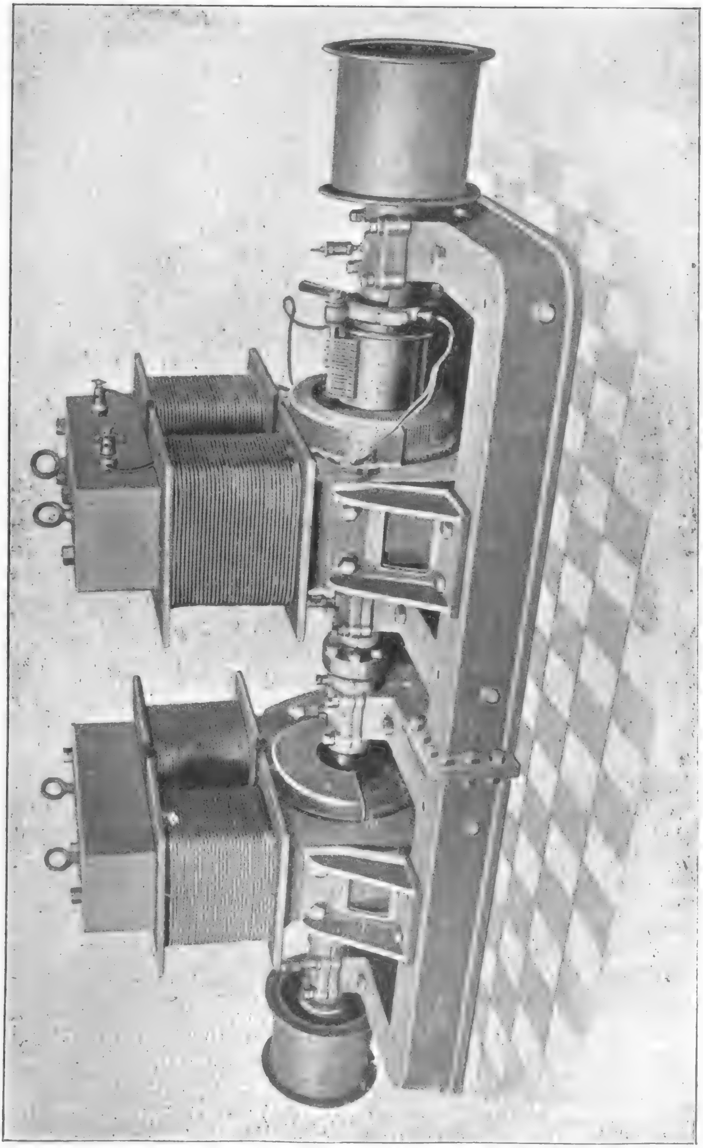


Fig. 79.—Arniston High-lift Pump Motors.

One objection that has been urged against electricity as a motive power for pumps is the difference in speed between the pump and the motor, which renders necessary the interposition of some form or other of speed-reducing gear. The nature of the work tells heavily on the gear, and in many cases renders it very liable to breakage. To overcome this difficulty pumps suitable for gearing direct to the motor have been designed. Such pumps ought to be more economical than those on which gear has to be employed, provided that other conditions are

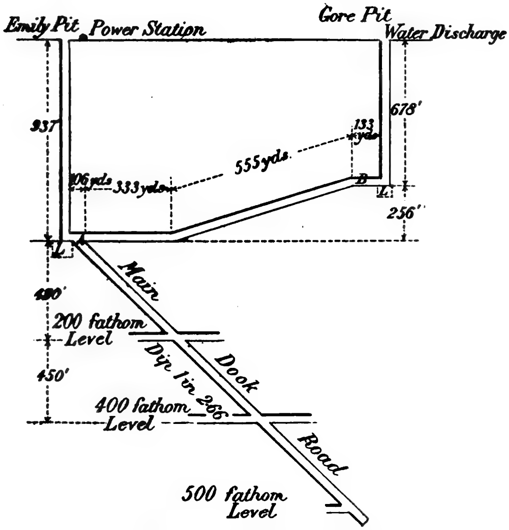


Fig. 80.—Diagram of Pumping Arrangements at Arniston Colliery.

A = 500-gallon pump, 11 inches diameter 18-inch stroke, with 80 H.P. motor.
B = 500-gallon pump, 11 inches diameter 18-inch stroke, with two 80-H.P. motors.
C = 100-gallon pump, 6 inches diameter 9-inch stroke, 25 H.P. motor.
D = 100-gallon pump, 6 inches diameter 9-inch stroke, 25 H.P. motor.
E = 100-gallon pump, 6 inches diameter 9-inch stroke, 25 H.P. motor.
L L = Lodgments.

similar. Economy of power, however, is not always the most important consideration that the mining engineer has to attend to, the question of maintenance and repair being of equal or even greater importance, and the inconvenience of interfering with the working of the colliery during enforced stoppage of the pumps being one especially to be guarded against.

The **Hatfield pump** is one which has been designed for connecting direct to the motor, and consists of three pump barrels arranged round the motor shaft, each pump making an angle of 120° with the other. The pump has an extremely short stroke which is about an inch, the speed being from 600 to 700 revolutions per minute.

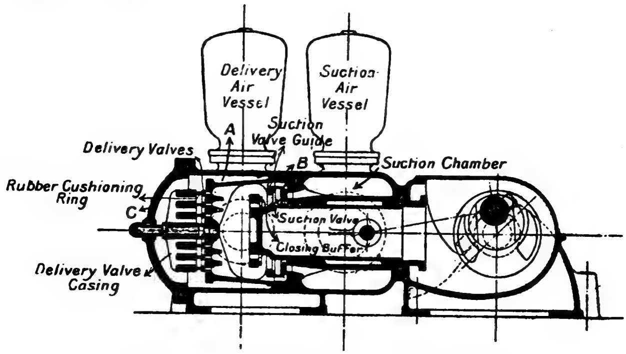


Fig. 81.—Section of Riedler Express Pump.

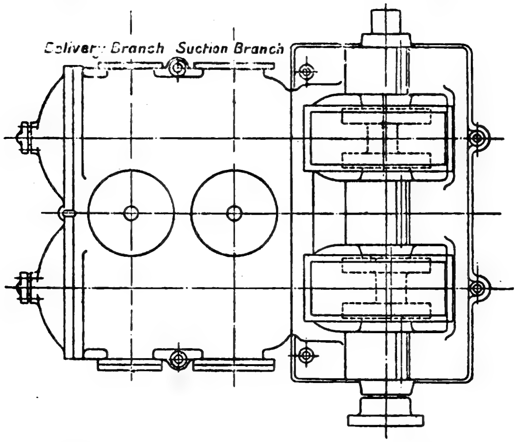


Fig. 82.—Plan of Riedler Express Pump.

Disc valves of india-rubber are used, and the starting of the pump against a head of water is rendered easier by providing a bye-pass valve between the suction and delivery water passages. The size of the pump barrels differs in the various pumps according to the nature of the work required.

The construction of the pump is very simple, and the test of time alone will show whether it is liable to break down or otherwise. Should wear and tear prove inconsiderable there is little doubt that it will find a ready acceptance among mine owners.

Another pump suitable for running at a high speed is the **Riedler express pump**, the latest form of which is shown in Fig. 81, which is a section of this pump, and of which Fig. 82 is a plan.

In this design there is a barrel, A, within the main pump body, B, the head or end of the barrel, **A**, forms the delivery valve seat, which may be part of the barrel or fitted on to the same. The delivery valve is supported upon a stem, which extends through the back cover, C, by means of a screw set up on this stem the whole of the internal parts are secured in position. After removing the back cover any one of the parts within the pump body may be withdrawn for inspection.

Arrangements are provided for connecting the suction and discharge pipes to either, or both sides of the pump if required, the openings in the pump body that are not required being fitted with blind flanges.

The pump is single-acting in each plunger. The suction chamber is contained in a casting extending round the plunger, and connecting the guide section to the pump body, upon which a suction air vessel is mounted. The sleeve gland containing the plunger extends through this suction chamber, up to the back of the suction valve seat, forming a water-tight joint between them. The suction valve is supported in an annular ring, which also guides the valve, and at the same time limits the opening according to the amount desired. The plunger is extended through the valve seat and valve, and the end turned down and fitted with closing ring or buffer, so adjusted that when the plunger is at the extreme end of the stroke the buffer has brought the suction valve down to its seat. The delivery valve is spring-loaded by means of a rubber ring.

The pump is designed to deal with heads of water up to 200 fathoms vertical, and where electrically driven should be of the three-throw type.

The maximum speed of these pumps is about 350 revolutions per minute.

If they are coupled direct to the motor one of comparatively large size will be required on account of the low speed, but this is not an absolute necessity, as spur gear can be used; and, as will be seen, the high speed of the pump reduces the gear required to a minimum.

These pumps have been adopted in a large number of mines in Germany, and are giving every satisfaction. For a given capacity they occupy little space, which means less expensive foundations, and less excavation should the pumps require to be placed underground. Their volumetric effect, as well as their mechanical efficiency, are both very high, features which are much in favour of this pump.

Any of the various types of differential Riedler pumps can be

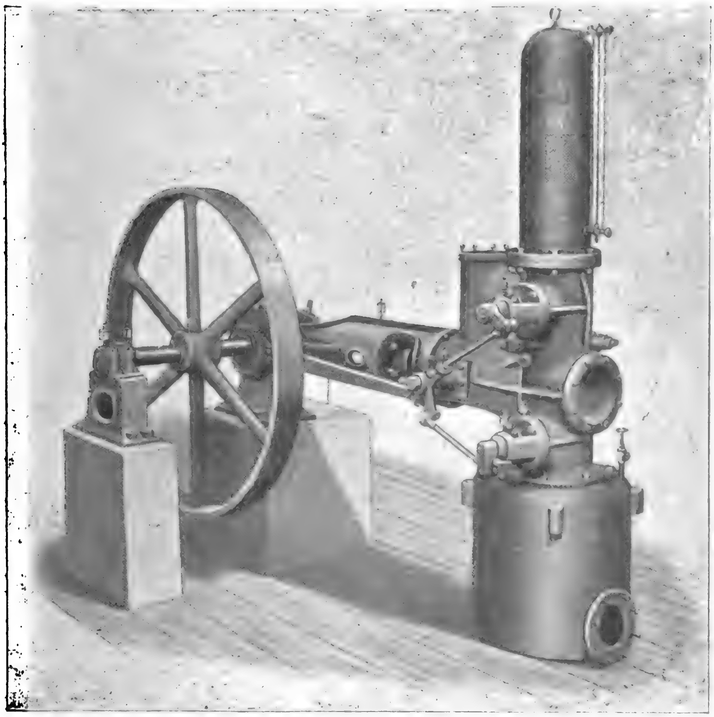


Fig. 83.—Single Differential Belt-driven Riedler Pump.

driven electrically if suitable connection with the motor be arranged, as the construction of the pumps is such that they present a uniform resistance to driving, a feature of importance where electric motors have to supply the power.

A single differential Riedler pump, having a capacity of 630

gallons per minute against a 65 feet head, and suited for driving by belt gear from a high-speed motor, is shown in Fig. 83.

Centrifugal Pumps.—These pumps may be considered as water fans, and their action may be described as follows :—

Inside a circular casing, C (Fig. 84), are placed blades, which

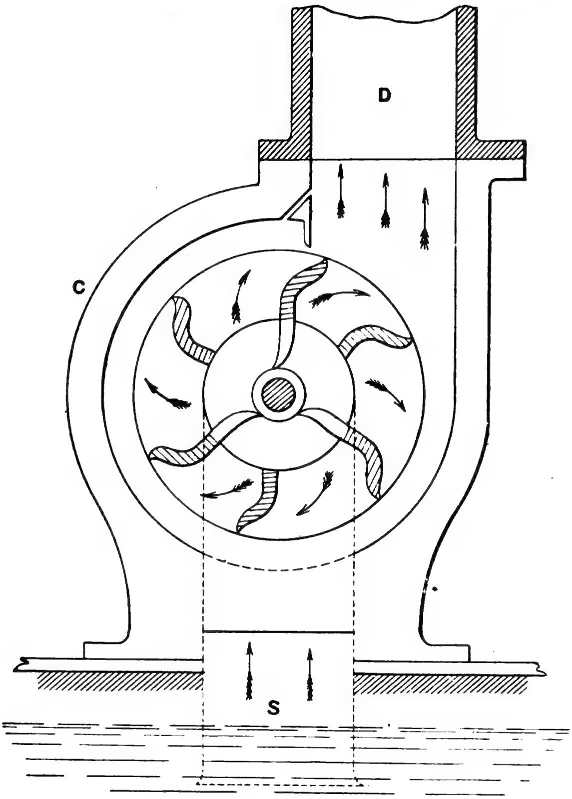


Fig. 84.—Centrifugal Pump.

C = Casing. | D = Discharge. | S = Suction.

are capable of being revolved, and which are curved both at the centre and at their circumference. When the pumps are run air is driven out, and water flows into the centre of the revolving disc. This is expelled outwards by centrifugal force, passes off through the discharge pipe, D, the arrows in the

diagram showing the direction of the flow. The force with which the water leaves the blades will depend upon the centrifugal force developed by the revolving disc, which again is dependent upon the motor which drives the pump. As the water flows from the centre a partial vacuum is produced which causes the water to rise up in the suction pipe to the pump. These pumps work best with a short suction pipe, or, better still, if the pump itself is partly under water. With electricity as the motive power this would hardly be practicable, but the suction pipe should always be of short length. The water is admitted to the revolving disc upon both sides, and after being driven to the extremities of the blades passes off into an annular space, from which it finds its way into the delivery pipe. This class of pump is best suited for lifts of about 20 feet or thereabouts, although this is not by any means its limit of application.

Centrifugal pumps have to be designed in such a way that neither eddies nor broken water occur during pumping; the vanes must be set at such an angle that the water enters and leaves the wheel without shock, and the sectional area of the water passage through the wheel must be constant. In practice the maximum speed of the water is not allowed to exceed 450 feet per minute.

To ascertain the size of such a pump when a known quantity of water has to be dealt with the following formula may be used:—

Let d = diameter of suction and discharge pipe in inches.
,, w = weight of water in lbs. per minute.
,, G = number of gallons of water per minute.
,, V = volume of water in cubic feet per minute.
,, D = diameter of wheel in feet.
,, H = height water is delivered in feet.
,, N = number of revolutions of wheel per minute.

$$\text{Then } d = \cdot 255\sqrt{G} = \cdot 6{:}8\sqrt{V} = \cdot 081\sqrt{w}.$$

In practice the diameter of the wheel is generally from two and a-half to three times the diameter of the suction pipe.

$$\text{Then } N = K\frac{\sqrt{H}}{D};$$

where K is a constant whose value is taken as 153 for small pumps, and 187 for large pumps.

As the water leaves the wheel of such a pump it is possessed of a radial velocity, as well as a velocity in the direction of motion of the wheel, but this velocity being the component of the other two velocities is the only one that has to be considered in estimating the work done by the pump.

Take the following as an example:—

A centrifugal pump discharges 180 cubic feet of water per minute, its component velocity in the direction of motion of the rim being 25 feet per second, while the rim itself travels at 30 feet per second. Find the theoretical H.P. required to drive the pump.

Three cubic feet of water are moved per second, the mass therefore $= \frac{3 \times 62{\cdot}5}{32{\cdot}2}$; 62·5 being the weight in lbs. of 1 cubic foot of water, and 32·2 the acceleration due to gravity.

This multiplied by the effective component gives

$$\frac{3 \times 62{\cdot}5 \times 25}{32{\cdot}2} = 145{\cdot}5 \text{ lbs.},$$

which is the momentum lost by the wheel per second. The work done per second will be this force multiplied by the speed of the wheel.

$$145{\cdot}5 \times 30 = 4365 \text{ foot-lbs. per second,}$$

$$\text{and H.P.} = \frac{4365 \times 60}{33{,}000} = 8 \text{ H.P. nearly.}$$

The work done per pound of water is

$$\frac{\text{Foot-lbs. of work per second}}{\text{Weight of water per second}} = \frac{4365}{3 \times 62{\cdot}5} = 23{\cdot}3 \text{ ft.-lbs.},$$

i.e., this energy would raise a pound of water to a height of 23·3 feet.

The efficiency of such pumps depends on the lift. With lifts of only a few feet, it is usually about 50 per cent. By increasing the lift the efficiency increases until, with about 20 feet, the efficiency reaches about 70 per cent.; beyond this, any increase in the height of lift decreases the efficiency until about 48 feet or so is reached, when the efficiency again becomes about 50 per cent.

The power required to drive such a pump can be found by dividing the foot-pounds per minute required to raise the water by the product of the efficiency and 33,000—*i.e.*,

$$\frac{\text{Foot-pounds expended in raising the water}}{\text{E} \times 33{,}000}.$$

The following may be taken as an example:—

A centrifugal pump has to raise 900 gallons of water per minute to a height of 36 feet vertical. Find the size of the discharge pipe, the diameter of the pump wheel, and the number of revolutions per minute; also, the B.H.P. of the driving motor.

By formula, $d = {\cdot}255\sqrt{\text{G}} = {\cdot}255\sqrt{900} = 7{\cdot}65$ inches.

Taking the wheel to be approximately two and a-half times the diameter of the discharge pipe, its diameter would be 18 inches or 1·5 feet. Then

$$\text{N} = 153 \times \frac{\sqrt{36}}{1{\cdot}5} = 153 \times 4 = 612.$$

At 36 feet head the efficiency would be about 60 per cent.

The work done is $900 \times 10 \times 36 = 324,000$ foot-pounds per minute.

$$\text{B.H.P. of motor} = \frac{324,000 \times 100}{33,000 \times 60} = 16{\cdot}4.$$

In many collieries, quantities of very dirty water have to be pumped. Where the head is not great, pumps of the centrifugal type, coupled direct to the driving motors, may be used. Such an arrangement may be adopted underground when conditions are suitable, but is more frequently met with in connection with the supply of water to coal-washing plant, for which purpose it is well suited.

Pumps of the above-mentioned class are capable of pumping water containing large quantities of suspended mud and gritty matter without injury, and, as they run at high speeds, they can always be coupled to the motor shaft direct. With low heads, these pumps are very efficient, and their first cost is low, since high-speed motors can be employed without the use of gear of any description.

In the *Electrical Review*,* Mr. W. C. Mountain refers to an installation of this type which was adopted to clear a flooded mine, and of which Fig. 85 is an illustration.

The pumping capacity of this plant was 1000 gallons per minute against a head of 150 feet, the speed being 700 revolutions per minute. The motor was one capable of giving 100 H.P., but was intended for use in connection with the permanent pumping plant which was laid down after the mine had been drained. The workings were to the dip, which was 1 in 12, and, as it was necessary to have the pumps portable, this type was adopted. The pumps were shifted every 80 yards, giving the extreme height of the pump above that of the water as 20 feet, which represents the total height to which the water was raised through the suction pipe. As will be seen from the illustration, the pumps were duplex, as it was necessary to run two in series to raise the water the required height. By the use of three pumps run in the same way, a head of 200 feet could be dealt with. This method of running of the pumps in series is required to raise the water against any considerable height, and consists of running the water through the different pumps one after the other, thus enabling the pumps to discharge their water against greater heads without abnormal increase of the velocity of their pump vanes. As the centrifugal pump has no valves and does not pump any water until the speed of rotation reaches a certain point, it starts under no load, and is thus very suitable for driving by means of induction motors using polyphase currents.

* 8th February, 1901.

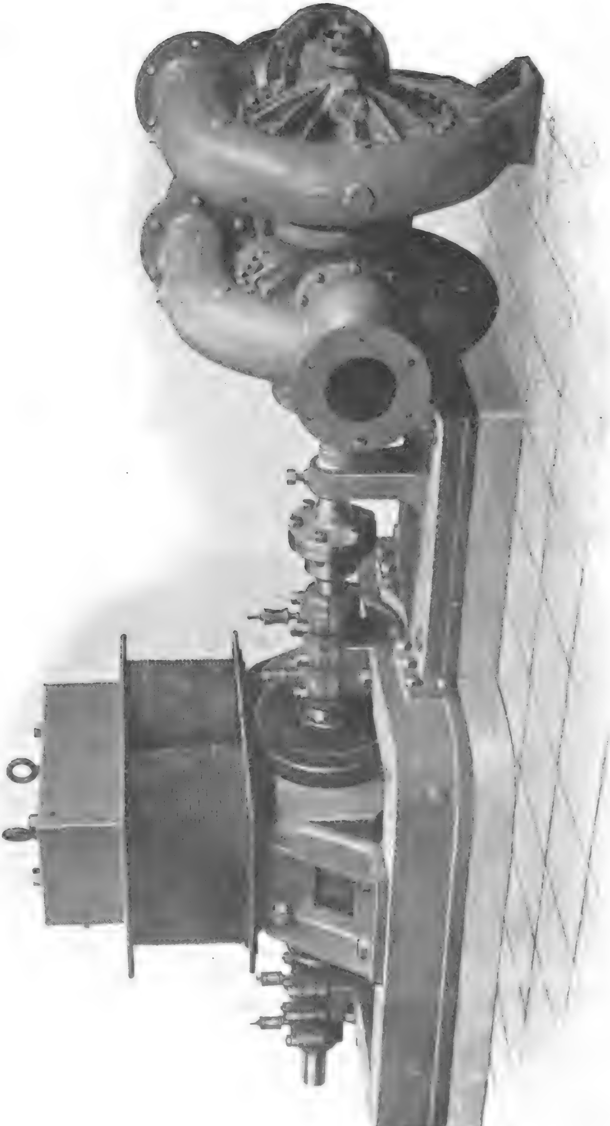


Fig. 85.—Duplex Centrifugal Pumps coupled to Motor.

Electrical Sinking Pumps.—Sinking operations have also been essayed with pumps driven by electricity, although the conditions usually met with in sinking a shaft are ill-suited to the successful working of electrical machinery. First of all, the pumps have to be suspended by a chain, so that they can be readily raised and lowered, which means that freedom from vibration cannot be obtained, and, as the motor has to be connected to the pumps direct by means of spur gear, it must suffer to some extent from this vibration. Then there is the likelihood of more or less water being found in the near vicinity of the pumps, which renders the keeping of the insulation of the cables intact a difficult matter, and likewise creates conditions unfavourable to the motor itself. In order to protect the latter, it has to be placed in a closed casing, which means that, in order to keep the temperature down, a more expensive motor has to be employed than would be necessary were it possible to run open.

On the other hand, the gear and shaft fittings for such a pump are reduced to a minimum, as only a suction and discharge column of pipes are necessary, the power being conveyed to the motor by the cables, which may be kept coiled on a drum at the pit top, and provided with an easy connection to the dynamo mains, so that no time will be lost in raising and lowering the cables along with the pump, and the connections in the shaft can always be kept intact. The power required to drive the pumps will also be obtained more economically than if steam were conveyed to the pumps direct, and will, at the same time, save further complications in the shaft. A pump suited for this class of work, and known as the **Jeanesville,** is made by an American firm, and consists of a set of three-throw pumps, partly enclosed, and fixed to a cast-iron frame which carries the reducing gear, the whole of which is enclosed. On the top of the mechanism the motor is fixed in a tight cast-iron case, which also carries the cable connections as well as the eyebolts for connecting the pump to the suspending chain or rope. This pump is shown in Fig. 86.

While electrically-driven sinking pumps are on the market, they have not as yet been very extensively employed, and it is not probable that they will rise into public estimation very rapidly, as conditions are not quite so much in their favour as would be the case were it possible to fix the pumps in position. This disadvantage will in many cases deter engineers from using them in preference to some of the other better known systems of dealing with water during sinking.

In regard to the relative advantages of pumping, by electricity

or other means, certain important points must be considered, and it might be well to note some of the more essential. In the first place, the plant should always have ample capacity for dealing with larger quantities of water than are generally met with. This should be ascertained by careful measurements, and the best method is to have a fair margin of power which could

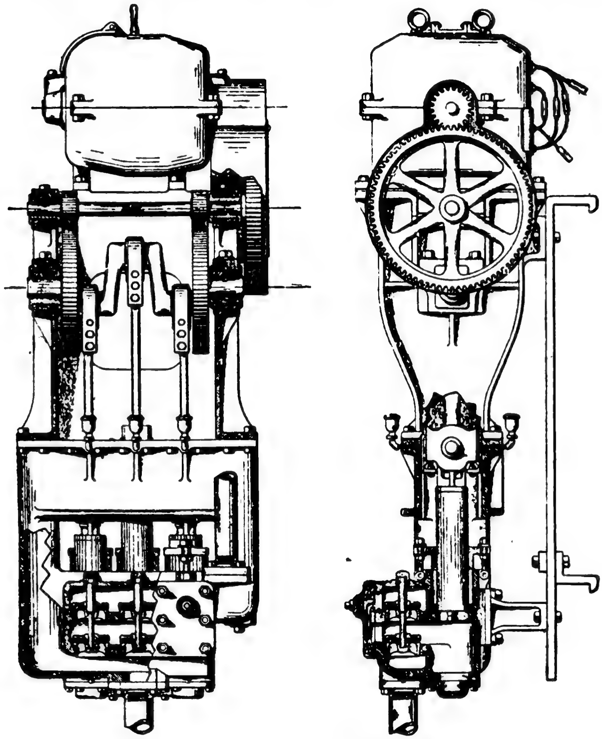


Fig. 86.—Jeanesville Sinking Pump.

be employed in the event of flooding, from whatever cause this might be due.

Storage capacity is also of importance, as it allows the pumps periods of rest, and leaves time for repairs should such be necessary.

In cases where large quantities of water have to be dealt with, it might often be an advantage to put down two sets of pumps, either of which would be able to deal with the water under

ordinary conditions, the plant being so arranged that both could be run simultaneously if required. Such a plant would have a greater first cost, but would last longer than if one only were employed, and would at the same time secure greater immunity from stoppage due to accident. It must be clearly understood that the author does not advocate this course as being peculiarly necessary with electrically-driven pumps; it is a method which should be observed no matter by what means the pumps are driven.

Should plant be placed underground, the size of the largest piece will depend on the appliances available for handling it, and the capacity of the shaft and roadways through which it must be conveyed. Furnished with data respecting these considerations, the designer of the pump will be able to construct a machine that will occasion the minimum of trouble in getting it into position.

Another most important point is the power required to work the pumps; this should always be largely in excess of the actual work done by the pump, as it must be borne in mind that friction is greatest just before motion takes place, and also, if the pump has to start under full load—*i.e.*, with the discharge column full of water—it must be remembered that water is possessed of inertia, which will have to be overcome, and that consequently the power required to start the pump is in excess of that required to keep it running once it has been set in motion. Since an electric motor does not give out its full power at starting until its speed has come up to the requirements of the design, such a motor will require a large margin of power if starting has to take place safely and easily under full load, and the author would recommend that not less than 50 per cent. be allowed. This is no drawback to the after working of the motor, as the larger the motor the higher the efficiency, and as motors only take current in proportion to the work they are doing, no increase in the working cost will follow the use of such a motor, even should it be kept working considerably under load.

The author has come across a number of cases where electric pumps have been installed without due regard being paid to the above conditions regarding their starting, with the result that, in each case, part of the water has had to be run off the column before starting could be carried out safely, or a bye pass had to be made between the tail and discharge pipes, fitted with a valve which was opened on starting, and closed gradually as the speed of the pumps approximated to the normal. Conditions such as these are sure to lead to trouble sooner or later, as

neglect of the necessary precautions when starting is likely to cause break down.

What makes the matter worse is that nearly all other forms of pumps can be started against the full head, without any preliminary precautions whatever, and the average workman in charge thinks that electrically-driven pumps should do the same, hence we have a fruitful source of trouble should the motor be installed too near its work. There is little doubt that many of the installations which have been put down with too little starting power have failed again and again, and such failures, instead of being ascribed to their true cause, have been used as an argument against the use of electricity as a motive power in general, and has to some considerable extent prevented the use, or at least delayed the adoption, of electric plant in many situations about collieries, where its application would have been accompanied with the very best results.

The situation of pumps is another matter that should always be very carefully considered, and the pumps should be so placed that they are in a good position for their work, not too high above the level of the water to be raised, and enclosed in such a way as to be free from accumulations of water standing about the floor, easy of access for repairs, and placed out of the way of the general traffic of the mine. Where electric pumps are placed at a shaft bottom, the house prepared for them should have a gentle slope towards the bottom, and the seating should be raised about a foot or so above the floor level as this tends to keep everything dry. The position of the pump should also be such that in the event of stoppage and water rising, this should be able to pass away and fill any dip workings that might exist before rising to such a height as to interfere with the motor. In such a case, even in the event of an enforced period of stoppage, all available space would be filled with water before the pumps were flooded out.

When pumping has to be done from some place where it becomes necessary to change the position of the pumps at frequent intervals, such as at the face of a dip during driving, portable pumps would be an advantage. Such pumps, of which Fig. 87 is an illustration, are mounted on steel girders which are fitted with wheels set to the same gauge as the colliery tubs, thus enabling the pumps to be shifted from place to place about the pit with little trouble. The plant shown is of the double-throw ram type, the rams being 6 inches in diameter with a 10-inch stroke, and geared to run at a speed of from 50 to 60 strokes per minute, the driving gear being a combination of belt and spur wheel. The motor is compound-wound, and

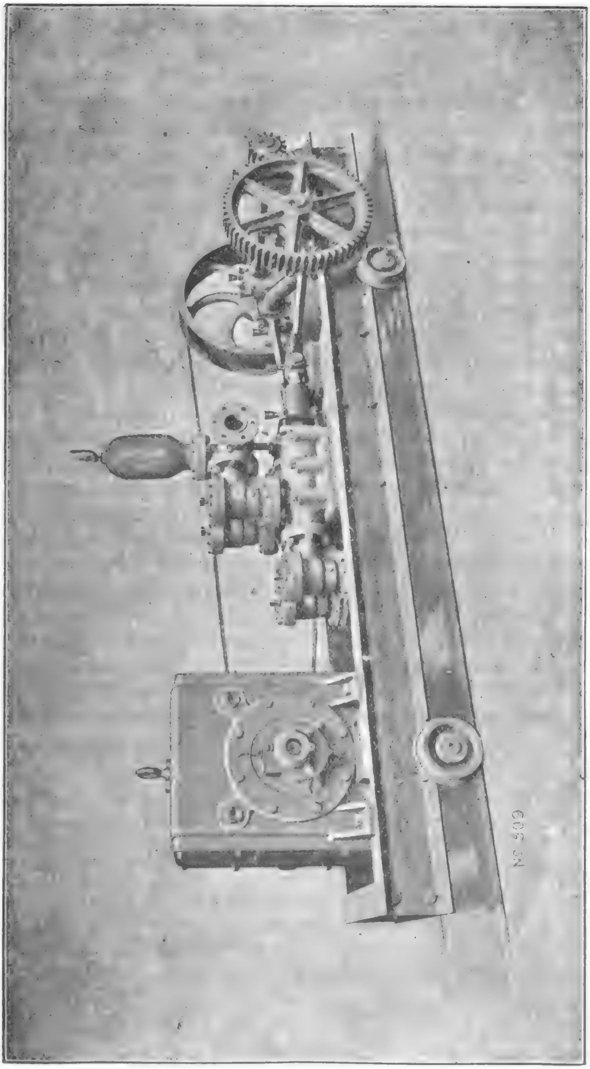


Fig. 87.—Two-throw Portable Ram Pump, combined with enclosed Electric Motor. Belt driven.

sits on the same seat as the pumps, being placed immediately behind them. This plant as shown was laid down for the Newton Coal Company, Acklington, by Messrs. Scott & Mountain. Where pumps of this class are in use, a drum containing a sufficient quantity of cable (which should be double) to allow the pumps to be shifted from point to point without jointing the cable too often, is a useful auxiliary to the arrangement. The motor-starting switch and resistance should be placed on the same carriage, as this course is preferable to fixing it anywhere along the side. A switch should always be put into the circuit in such a way that it can be used for opening the circuit should the generator stop, or if it becomes necessary to do something to the motor when an opportunity presents itself, as this would act as a safeguard against a possible shock being given to the attendant should the circuit remain closed. This switch would only be used for the purpose indicated, and the motor would be set in motion and stopped by means of its own starting switch in all cases.

For all forms of electrical pumping about a mine, where plant is installed for that purpose, a voltage of 420 at the generator can be adopted with safety and economy, under most circumstances, and it should always be borne in mind by the purchaser of electric plant that, although high speed in the motor reduces first cost, it is seldom that economy follows the use of high speeds, especially where much power has to be transmitted, and speeds varying from 500 to 700 revolutions per minute, according to the power of the motor, are, in the author's opinion, best suited to the usual conditions of pumping met with in average mines. The pumps should be substantially fitted in all respects, and should be provided with ample bearing surface at all bearings, and fitted with the best appliances for lubrication. When the pumps are used to force water to a height of more than about 160 yards, it is considered good practice to provide double gearing for them—*i.e.*, spur wheels on each side of the shaft, and, by preference, such gear should be machine cut.

Where small pumps are at work pumping water from a sump or lodgment, and where the presence of an attendant during the whole time of working would be too expensive, the current can be made to stop the motor automatically when the surface of the water is lowered to a given point, and also to start it again, when the water has risen to the desired height. This is done by a float connected to a switch in such a way that when the water carrying the float reaches a pre-arranged point a projecting lever is moved so as to throw over a weight which opens the circuit. The circuit is closed in the same way when the water rises to

the desired point, the motor being started with a resistance in circuit with the armature to prevent damage. As the motor gets up speed this resistance is gradually cut out. Such an arrangement is shown diagrammatically in Fig. 88, and can only

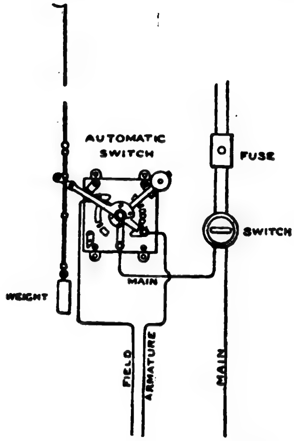


Fig. 88.—Automatic switch.

be worked safely when the motor circuit remains continually closed, otherwise there is risk to the motor. It has already been pointed out that in the case of discharge or suction pipe the velocity of the water should not exceed 4 feet per second, as it is liable to interfere with the proper working of the pump, and at the same time it increases the frictional resistance to flow in proportion to the square of the speed. The frictional resistance to the flow of water in a pipe will vary with the nature of the inside surface, and also with the bends on the column, should such exist, but the following tables may be of some use as giving the approximate loss of head in feet for every 100 feet of pipes that the water passes through :—

Inside Diameter of Pipe in Inches.

Velocity in Feet per Second.	1-inch Inside.	2-inch Inside.	3-inch Inside.
	Loss of Head in Feet.	Loss of Head in Feet.	Loss of Head in Feet.
2	2·37	1·18	·79
2·2	2·8	1·4	·93
2 4	3·27	1·63	1·09
2·6	3·78	1·89	1·26
2·8	4·32	2·16	1·44
3·0	4·89	2·44	1·62
3·2	5·47	2·73	1·82
3·4	6·09	3·05	2·04
3·6	6·76	3·38	2·26
3·8	7·48	3·74	2·49
4·0	8·2	4·1	2·73
	4-inch Inside.	5-inch Inside.	6-inch Inside.
2	·59	·47	·39
2·2	·70	·56	·46
2·4	·81	·65	·54
2·6	·94	·75	·63
2·8	1·08	·86	·72
3·0	1·22	·97	·81
3·2	1·37	1·09	·91
3·4	1·52	1·22	1 02
3·6	1·69	1·35	1·13
3·8	1·87	1·49	1·25
4·0	2·05	1·64	1·37
	7-inch Inside.	8-inch Inside.	9-inch Inside.
2	·33	·29	·26
2·2	·40	·35	·31
2·4	·46	·41	·36
2·6	·54	·47	·42
2·8	·61	·54	·48
3·0	·69	·61	·54
3·2	·78	·68	·60
3·4	·87	·76	·68
3·6	·96	·84	·75
3·8	1·07	·93	·83
4·0	1·17	1·02	·91

INSIDE DIAMETER OF PIPES IN INCHES—*Continued.*

Velocity in Feet per Second.	10-inch Inside. Loss of head in Feet.	11-inch Inside. Loss of Head in Feet.	12-inch Inside. Loss of Head in Feet.
2	·23	·21	·19
2·2	·28	·25	·23
2·4	·32	·29	·27
2·6	·37	·34	·31
2·8	·43	·39	·36
3·0	·48	·44	·40
3·2	·54	·49	·45
3·4	·61	·55	·51
3·6	·67	·61	·56
3·8	·74	·68	·62
4·0	·82	·74	·68
	13-inch Inside.	14-inch Inside.	15-inch Inside.
2	·18	·16	·15
2·2	·21	·20	·18
2·4	·25	·23	·21
2·6	·29	·27	·25
2·8	·33	·30	·28
3·0	·37	·34	·32
3·2	·42	·39	·36
3·4	·47	·43	·40
3·6	·52	·48	·45
3·8	·57	·53	·49
4·0	·63	·58	·54

The following may be taken as as example of the use of the foregoing tables :—

Find the head due to friction of the water in an 11-inch pipe when the velocity is 3 feet per second, the length of the pipe being 1200 feet.

From the tables we see that for 3 feet velocity per second the loss of head in an 11-inch pipe is ·44 per 100 feet.

$$\therefore \quad \frac{1200}{100} \times \cdot 44 = 5 \cdot 28 \text{ feet.}$$

This would have to be taken into account in fixing the power of the motor, as no matter what the actual head may be this additional quantity would have to be added as the power spent in overcoming friction at that particular velocity.

Pipes may be of cast iron, or they may be of wrought iron or steel. When of cast iron they are usually made in 9-feet lengths,

while longer lengths up to 15 and 20 feet are common when the material used in their construction is wrought iron or steel. Where cast-iron pipes are used they should be well coated with pitch both inside and out, as it forms a capital preservative and at the same time diminishes the friction of the water. Such pipes are best cast on end, as the thickness is then likely to be more uniform. Wrought-iron and steel pipes are becoming more common on account of their lower cost, greater security against shock, and the greater facilities they afford for handling and fitting into position. Whatever class of pipe may be used it is of importance to see that they are put in of ample strength. The following formula will give the necessary thickness:—

Let P = pressure of water in lbs. per square inch = head in feet × ·434.
,, d = diameter in inches.
,, t = thickness in inches.
,, F = factor of safety, say not less than 6.
,, T = tensile strength of material.

The tensile strength of cast iron is about	16,000 lbs. per square inch.		
,, ,, wrought iron ,,	48,000	,,	,,
,, ,, mild steel ,,	60,000	,,	,,

$$\text{Then thickness} = \frac{P \times d \times F}{2 \times T}.$$

In practice cast-iron pipes are not made of less thickness than $\frac{3}{8}$ of an inch no matter how small the pressure they have to stand, for thicknesses above $\frac{3}{8}$ the formula given above would hold good.

As an example of the use of the above formula the following may be taken:—

Find the thickness of a cast-iron pipe, 10 inches diameter, to stand the pressure due to a head of 600 feet.

$$\begin{aligned} \text{Here } P &= 600 \times {\cdot}434 = 260{\cdot}4 \text{ lbs.} \\ d &= 10 \text{ inches.} \\ F &= 6, \text{ say.} \\ T &= 16{,}000. \end{aligned}$$

$$\text{Then thickness} = \frac{260{\cdot}4 \times 10 \times 6}{2 \times 16{,}000} = {\cdot}49 \text{ inch, say } \tfrac{1}{2} \text{ inch.}$$

For the same conditions should wrought iron be used the pipe would have a thickness of about $\frac{1}{6}$ of an inch since its tensile strength is three times as great.

The power required to drive pumps will vary with the circumstances, but the following examples may be taken as illustrative of the method of ascertaining the size of motor and pumps to perform a given amount of work under certain specified conditions.

Two hundred and forty gallons of water per minute has to be raised to a height of 300 feet vertical. Find the size of three-throw pumps required, the horse-power of driving motor, and the number of amperes of current required, with 400 volts at the motor if motor efficiency is 90 per cent.

Pumps being three-throw each pump will raise $\frac{240}{3} = 80$ gallons per minute.

$$\text{By formula } d = 1{\cdot}176\sqrt{\frac{G}{{\cdot}034 \times S}}$$

taking S as 60 feet per minute.

$$\text{Then } d = 1{\cdot}176\sqrt{\frac{80}{{\cdot}034 \times 60.}} = 7{\cdot}36, \text{ say } 7\tfrac{1}{4} \text{ inches.}$$

With this diameter of ram the stroke might be 12 inches, in which case the crank shaft driving the rams would require to make 60 revolutions per minute. The work done would be equal to that of raising the water through 300 feet. Since a gallon of water weighs 10 lbs., and 240 gallons have to be raised per minute, the work done will be $240 \times 10 \times 300 = 720{,}000$ ft.-lbs. per minute, and H.P. $= \frac{720{,}000}{33{,}000} = 21{\cdot}8$, say 22 H.P. To allow for friction and inertia of water at starting add 50 per cent. and we have 33 B.H.P. to be given at the motor shaft.

Since the motor has 90 per cent. efficiency, and the voltage is 400, the amperes required will be as follows :—

$$\text{Amperes} \times 400 = \frac{746 \times 33 \times 100}{90} = 68{\cdot}3, \text{ say 69 amperes.}$$

As a further example of dealing with water from dip workings the following may be taken :—

Ninety gallons of water per minute has to be raised from the bottom of a dook which is 400 yards long, the dip being 1 in 5, what size of pumps will be required, and what the horse-power of the driving motor? If the flow of water in the discharge be about 3 feet per second what will be the size of pipes required?

Adopting three-throw pumps we have $\frac{90}{3} = 30$ gallons per minute for each pump.

Suppose slip leakage, &c., to be 20 per cent., then $30 + \frac{1}{5}$ of $30 = 36$ gallons to be calculated for.

Taking 60 feet per minute as the pumping speed the

$$D = \sqrt{\frac{G}{{\cdot}034 \times S}} = \sqrt{\frac{36}{{\cdot}034 \times 60}} = 4{\cdot}19, \text{ say } 4\tfrac{1}{4} \text{ inches.}$$

Taking an ordinary proportion the length of stroke might be 8 inches, then the number of revolutions of the crank shaft would be 90 per minute.

The size of discharge pipes would come in as follows :—$90 \times {\cdot}16 = 14{\cdot}4$ cubic feet per minute.

If D represent the diameter of discharge pipe in inches then area in square feet $= \frac{D^2 \times {\cdot}7854}{144.}$

This, multiplied by the velocity of the water in feet per minute, is equal to the quantity discharged in cubic feet per minute.

$$\therefore \quad \frac{D^2 \times \cdot 7854}{144} \times 60 \times 3 = 14 \cdot 4,$$

$$\text{and } D = \sqrt{\frac{14 \cdot 4 \times 144}{\cdot 7854 \times 3 \times 60}} = 3 \cdot 83, \text{ say 4 inches.}$$

Pipes would be 4 inches diameter, and from the tables we see that a pipe of this size loses 1·22 feet of head per 100 feet of pipe when velocity is 3 feet per second. Thus loss of head due to friction of pipes $= \frac{400 \times 3 \times 1 \cdot 22}{100}$ = 14·64 feet, say 15 feet.

Work done in raising water, including the above loss, is

$$\left(\frac{400 \times 3}{5} + 15\right) \times 90 \times 10 = 229{,}500 \text{ ft.-lbs. per minute,}$$

and is got by multiplying the vertical height in feet, including that due to friction by the weight of the gallons raised per minute in lbs., which gives foot-pounds per minute.

$$\text{The H.P.} = \frac{229{,}500}{33{,}000} = 6 \cdot 9, \text{ say 7.}$$

To allow for friction of gear, starting, &c., add about 50 per cent., this will give a motor of about 10 B.H.P. as the size required.

Such a motor will be of ample strength for the work, and might run about 630 revolutions per minute, at this speed the gear would be $\frac{630}{90}$; that is, 7 to 1.

Suppose that in the above example the motor has an efficiency of 80 per cent., and it has to be supplied with current at 380 volts, what size of cables would you put in? What would be the voltage at the pit bottom, and how many amperes of current would the motor require?

Ten B.H.P. is required, and this represents 80 per cent. of the current energy.

$$\therefore \quad \frac{10 \times 100}{80} = \frac{\text{amperes} \times 380}{746}$$

$$\therefore \quad \text{Amperes} = \frac{10 \times 100 \times 746}{380 \times 80} = 24 \cdot 5.$$

On consulting the tables given in Chapter I. we find a cable of 19/19 will carry this current safely. Since the pump is 400 yards from the pit bottom the cables will have a total length of 800 yards from that point, and the drop in voltage will be 24·5 × 1·786 = 44 volts per mile nearly, which for 800 yards gives $\frac{44 \times 800}{1760} = 20$ volts.

The voltage at the pit bottom will thus be 380 + 20 = 400.

The efficiency of electrical pumping installations, taken as a whole, differs widely in different cases, but may be taken as from 45 to 75 per cent. according to conditions. Under ordinary

circumstances, with not too great a distance between the pumps and the generator, an average of from 55 to 60 per cent. should be obtained.

Alternate currents are now being applied to the driving of pumps, three-phase motors being the class generally used. Where adopted, good work is, as a rule, being done, and the future will see a more extended use of the system, especially in cases where power has to be carried over long distances. The principle of the action of three-phase motors has already been dealt with, and, where they are applied to pumping, the construction of the pumps in no way differs from that of those driven by the continuous current motor.

EXAMPLES.

1. Find the head due to friction in an 8-inch pipe when the velocity of the water is 4 feet per second, the length of pipe being 2000 feet.—*Ans.* 20·4 feet.

2. What is the head due to friction in a 4-inch pipe when the velocity of the water is 3 feet per second and the length of pipes 500 fathoms?—*Ans.* 36·6 feet.

3. A cast-iron pipe, 10 inches internal diameter, has to stand a pressure due to 80 fathoms head of water. Taking the tensile strength of cast iron as 16,000 lbs. per square inch, and allowing a factor of safety of 8, find thickness of pipe.—*Ans.* ·52 inch.

4. What must be the diameter of a pipe to carry 300 gallons of water per minute, if the velocity of the water is not to exceed 3 feet per second? —*Ans.* 7 inches diameter.

5. Find the thickness of a cast-iron pipe, 12 inches internal diameter, to stand the pressure due to a head of 150 fathoms of water, taking the factor of safety as 8 and the tensile strength of cast iron as 16,000 lbs. per square inch.—*Ans.* 1·17 inches.

6. A pump has to raise 180 gallons of water per minute from a dook. Find the size of the discharge pipe if the velocity of the water flowing through it is 4 feet per second.—*Ans.* 4·6 inches diameter.

7. A centrifugal pump has to raise 1000 gallons of water per minute to a vertical height of 25 feet. Find size of suction and discharge pipe, diameter of pump wheel, and number of revolutions per minute; also, if efficiency of pump be 70 per cent., find B.H.P. of motor.—*Ans.* Suction, 8 inches diameter; wheel, 20 inches diameter; revolutions, 460 per minute; B.H.P., 11.

8. A centrifugal pump has to raise 500 gallons of water per minute to a height of 40 feet. If its efficiency be 50 per cent., find the B.H.P. of the driving motor, the size of suction and discharge pipe, the diameter of the pump wheel, and the number of revolutions per minute.—*Ans.* 12·1 B.H.P., 5·7 inches diameter, 15 inches diameter, 765 revolutions.

9. A dook pump has to raise 150 gallons of water per minute from a dook 750 yards long with an inclination of 1 in 6. Three-throw electric pumps are to be used, the pumping speed being 60 feet per minute. Allowing 20 per cent. for slip, find size of pumps. What allowance would you

make for friction of water in pipes if velocity is 4 feet per second, and what power of motor would you use if 50 per cent. be allowed for all losses in motor and gearing, &c.?—*Ans.* Pumps, 5¼ inches diameter; stroke, 1 foot, crank shaft making 60 revolutions per minute; friction, equal to 50 feet vertical head; motor, 38·6 H.P.

10. In the above question (9) 38·6 is the E.H.P. that must be supplied to the motor. If the voltage at the motor is 380, what number of amperes will be required, and what size of cables would you use?—*Ans.* 76 amperes nearly; cables would do at 37/18 size.

11. A dook 500 fathoms long, dip 1 in 5, gives off 100 gallons of water per minute. Give a description of the electrical arrangement for pumping this water, pump to stand twelve hours in the twenty-four. Give the approximate H.P. of the motor, dynamo, and engine; also, the size of cables and voltage.—*Ans.* 62 H.P. for motor, this allows for 50 per cent. additional work; pumps, three-throw 6 inches diameter and 10-inch stroke; 72 revolutions per minute; cables, 37/16 size; dynamo, 74 H.P.; engine, 85 B.H.P.

CHAPTER VII.

HAULAGE.

THE applications of electricity to underground haulage have not developed quite so rapidly as have its applications to some other branches of colliery work. One of the chief reasons for this is that in many cases the haulage can be worked from the pit bank, and the steam power applied *direct* to its propulsion. When such is the case there is nothing to be gained, under generally existing conditions, by using electricity. No doubt at some future period many collieries will be fitted up electrically from their commencement, a generating station with the most economical machinery being laid down, and the power provided for carrying out the whole of the various operations of pumping, winding, haulage, &c., from this source. Economy will be secured by uniformity of system and the use of high steam pressures and engines using the steam under the most economical known conditions, but until this development takes place it will only be under certain circumstances that main haulage plants will be driven electrically.

For secondary haulage electrically driven plant is likely, under nearly all circumstances, to be the most economical, even under our present systems of working, and it is in connection with this branch of haulage that the greater number of existing plants have been laid down.

Whether the haulage be main or secondary it may be divided into four systems, namely :—

(1) *Direct acting* or *dook haulage.*
(2) *Main and tail rope haulage.*
(3) *Endless rope haulage.*
(4) *Endless chain haulage.*

The system is always determined by existing circumstances, and it not unfrequently happens that two or more systems may be in operation in different sections of the same colliery.

In the case of direct haulage the loaded tubs have to be drawn uphill, the empties gravitating back and carrying the haulage rope along with them. The grade must be sufficient to admit of this (not less than 1 in 25), and uniform. The haulage gear and motor is best placed at the top of the incline in such a

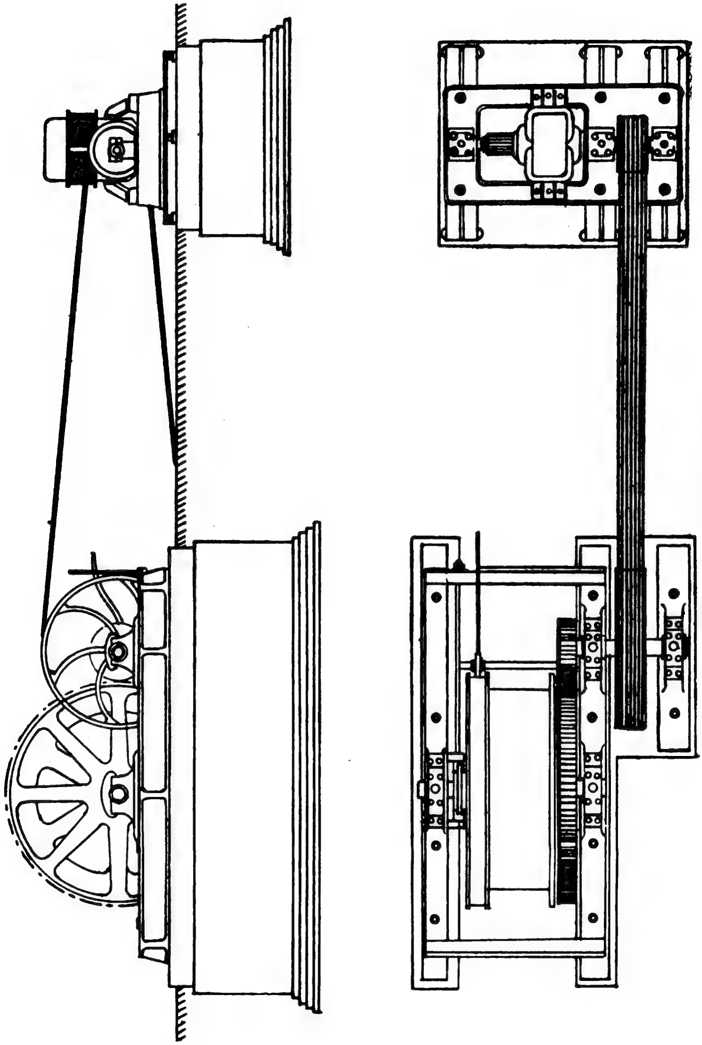


Fig. 89.—Dook Haulage.

situation that the person in charge can see his train when it comes to the landing place.

In this system a single road is all that is necessary unless a very large output is contemplated, in which case the road may be double. If a single road be used, one drum only is necessary, if a double road, two drums. These drums must be fitted with clutches and brakes, so that they can be thrown out of gear when necessary. The maximum speed with a well laid road may be taken as 10 miles an hour. The average speed, however, will be less than this, depending upon length of run, power of motor, and general facilities for getting up speed.

Where the situation of the motor is dry it may be arranged to drive the drum by belt, and when this is done the motor must be fitted with a sliding bed plate and tightening screws to permit of easy adjustment of the tension of the belt. An extension of the bed plate to allow a third bearing to be fitted outside the driving pulley, so that the pulley runs between two bearings, is an important feature, especially where the work is heavy. The motor must be fitted with resistance coils so that the speed of running can be regulated. Where the mine is a fiery one all parts must be enclosed in gas-tight cases so as to prevent accident should sparking take place. Should the situation be unfavourable to belt driving, gearing may be employed. This would render the plant more compact and reduce the cost of excavation of the site, but would increase the cost of the plant itself.

The general method of arrangement of such a plant is shown in Fig. 89.

In this case where the drum can be thrown out of gear by the clutch, the motor only requires to run in the one direction, and need not be provided with a reversing switch. Fig. 89*a* shows a geared plant for the same purpose.

Where the grade is uniform the motor may be series wound, as this form of winding gives the greatest starting power, and runs well where the load is not subject to variation.

The voltage will be determined by the distance from the generator, coupled with the conditions the generator may have to fulfil in supplying current to other plants, situated in other parts of the mine. The voltage may be from 210 to 420 volts,* according to distance, the higher voltage being used the further the power has to be transmitted. The motor room could be lighted from the mains; with the lower voltage one lamp in parallel would be used, with the higher voltage two lamps in

* The use of currents at from 400 to 500 volts pressure is now generally adopted about collieries.

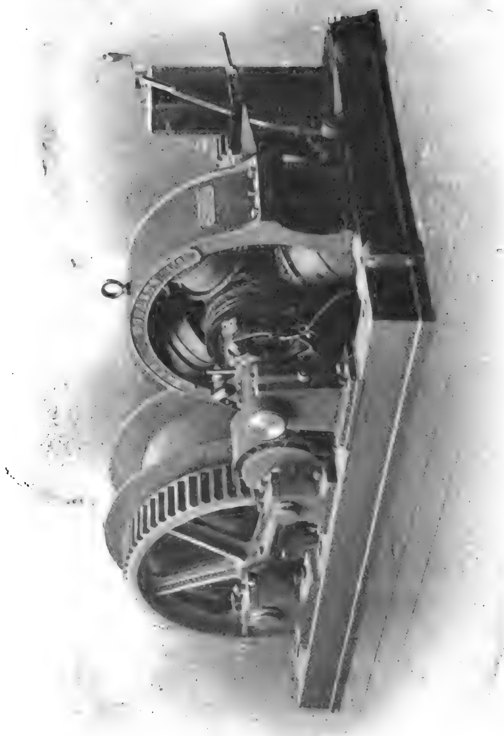


Fig. 89a.—Direct Acting Dook Haulage.

series with each other, and in parallel with the mains, could be adopted.

The size of motor required to perform a certain amount of work will be best shown by taking an example.

If the output is 200 tons in seven and a-half hours, the weight of the tub 4 cwts. tare, 14 cwts. gross = 10 cwts. of coal nett, and the inclination 1 in 10, then, with a length of incline of 250 fathoms = 500 yards each way, and a maximum speed of rake 10 miles an hour = 880 feet per minute, or an average speed of, say, 6 miles an hour = 528 feet per minute.

$$\text{Then, time running} = \frac{500 \times 2 \times 3}{528} = 5{\cdot}7 \text{ minutes per rake.}$$

$$\text{And time changing} = \text{say} \quad 5{\cdot}3 \quad ,, \quad ,,$$

$$\text{Total time per rake} = 11{\cdot}0 \text{ minutes.}$$

$$\frac{7{\cdot}5 \times 60}{11} = 41 \text{ nearly, say 40, rakes per day.}$$

$$\frac{200}{40} = 5 \text{ tons of coal per rake.}$$

5 tons = 10 tubs.

10 × 14 = 140 cwts. gross load.

Rope, say, 2 lbs. per yard = 1000 lbs.

Then, 15,680 lbs. = weight of coal and tubs. Taking friction as $\frac{1}{70}$, $\frac{15,680}{70} = 224$ lbs. 1000 lbs. = weight of rope. Taking rope friction at $\frac{1}{20}$, $\frac{1000}{20} = 50$ lbs.

The total resistance to be overcome is the sum of the resistances due to gravity and friction. At the maximum speed, 880 feet per minute, the work done against gravity is $(15,680 + 1000) \times \frac{880}{10} = 1,467,840$ ft.-lbs.; work against friction is $(224 + 50) \times 880 = 241,120$ ft.-lbs.

Total work is, therefore, 1,467,840 + 241,120 = 1,708,960 ft.-lbs., and the H.P. $= \frac{1,708,960}{33,000} = 51{\cdot}7$, or, say, 52. Taking the efficiency of the motor as being 80 per cent., then the actual H.P. required will be $\frac{52 \times 100}{80} = 65$.

Suppose the speed of the motor to be 600 revolutions per minute when developing 65 H.P., then the gear required will be as follows:—

Take drum as being 8 feet in diameter, then the circumference = $8 \times 3{\cdot}1416 = 25{\cdot}12$ feet. With a speed of 880 feet per minute, maximum, $\frac{880}{25{\cdot}12} = 35$ revolutions of drum per minute. Since the motor runs at 600, the gear is in the proportion of 35 to 600, or, roughly, 1 to 17. The drum might have a pinion driven by a spur wheel geared $4\frac{1}{4}$ to 1, the spur wheel shaft being driven by belt from motor at 4 to 1, then total gear

$\frac{4\frac{1}{4}}{1} \times \frac{4}{1} = \frac{17}{1}$. Therefore, motor makes 17 revolutions for 1 revolution of drum.

Suppose that in the foregoing problem a large generator is already installed, the working pressure of which is 400 volts, find the number of amperes of current required to work the motor.

$$1 \text{ H.P.} = 746 \text{ watts.}$$
$$\therefore 746 \times 65 = 48{,}490 \text{ watts,}$$
$$\text{and volts} \times \text{amperes} = \text{watts.}$$
$$\therefore 400 \times \text{amperes} = 48{,}490$$
$$\therefore \text{amperes} = \frac{48{,}490}{400} = 121 \text{ (nearly).}$$

Referring to the tables of Chapter I., we see that to carry this current safely cables of 37/16 S.W.G. will be required.

In the foregoing problem ample allowance has been provided for all sources of loss, and, if necessity arose, the output could be increased by at least 25 per cent. without trouble. At the same time, it is always desirable to have ample power, the small extra expenditure at first being more than compensated by immunity of risk from breakdown, which always exists should a plant be pushed beyond its capacity.

Main and Tail Rope Haulage.—This system is adopted in cases where the grade is irregular, or where the roof may be of such a nature that a single road is wide enough to keep open profitably. Two drums are used, both being usually fixed on the same shaft and worked by means of clutches. One drum carries the main rope, the other the tail rope. The load rake is drawn forward from the extreme end of the road by means of the main rope; the tail rope, being fastened behind the rake, is dragged out along with it. On arrival of the rake at the outside end of the road, the two ropes are transferred to the empty rake, which is dragged inbye by means of the tail rope, the main rope following behind. The two drums are thus both in operation at the same time, one being driven by the motor, the other running loose on the shaft and in the opposite direction, but controlled by a brake. Where the grade is downhill with the load rake, the tubs composing the rake are prevented from over running the main rope by the person in charge holding on to the end of the rake, by means of the tail rope with its drum and brake. The speed of running may be as much as 12 miles an hour, but depends greatly on conditions. Any number of branch roads can be worked without serious loss of time, the chief drawback being the high speed and consequent destruction of plant should the rake become derailed. Usually when this occurs, a considerable time is lost in getting operations recommenced, and often many of the tubs sustain serious damage. The rapid speed of running causes considerable wear of the rope; this, and the great length of rope required (the tail rope is itself

double the length of the road), is another disadvantage of this system.

Since only one set of tubs can be on the road at a time, the output is necessarily limited by the length of the road.

Arrangements have to be provided for throwing the drums in or out of gear as required. This is usually done by clutches or sliding carriages, the clutch giving the greater advantage, as both drums can be placed on the one shaft. Where the drums are run thus, they should be fitted with brass bushes as the wear is considerable. The shaft should also be made so as to allow for wear.

The power required will have to be arranged with regard to the steepest inclination, and greatest number of tubs required in the set, this condition often has the effect of causing a high cost for plant, as the motor may have to be made much larger for the sake of one little steep place on the road.

The alterations of grade (if existing) will cause a variation of the load, and in order to get constant speed under such conditions a shunt-wound motor would be employed, or a few turns of series coils might be added to the windings so as to increase its starting power under load.

A general idea of the type of plant in use for main and tail rope haulage may be gathered from the illustration shown in Fig. 90.

Further particulars regarding methods of working branches, attachment to rope, &c., may be found in the standard text-books on coal mining.*

As an illustration of how to find the requisite size of motor for given conditions, the following example may be taken :—

A main and tail rope has to draw 400 tons per day of eight hours, from a distance of 1600 yards; the speed is 8 miles an hour on the average, and the heaviest grade on the road is 1 in 10. The tubs weigh 4 cwts. empty, and hold 10 cwts. of coal. Find the number of tubs per rake, and the size of motor required to do the work if the drum be 8 feet diameter and the motor runs at 560 revolutions per minute.

$$\text{Speed of rake} = \frac{8 \times 5280}{60} = 704 \text{ feet per minute.}$$

$$\text{Time running} = \frac{1600 \times 3 \times 2}{704} = 13{\cdot}6 \text{ minutes.}$$

Allow 6·4 minutes for changing, then total time per rake is 13·6 + 6·4 = 20 minutes.

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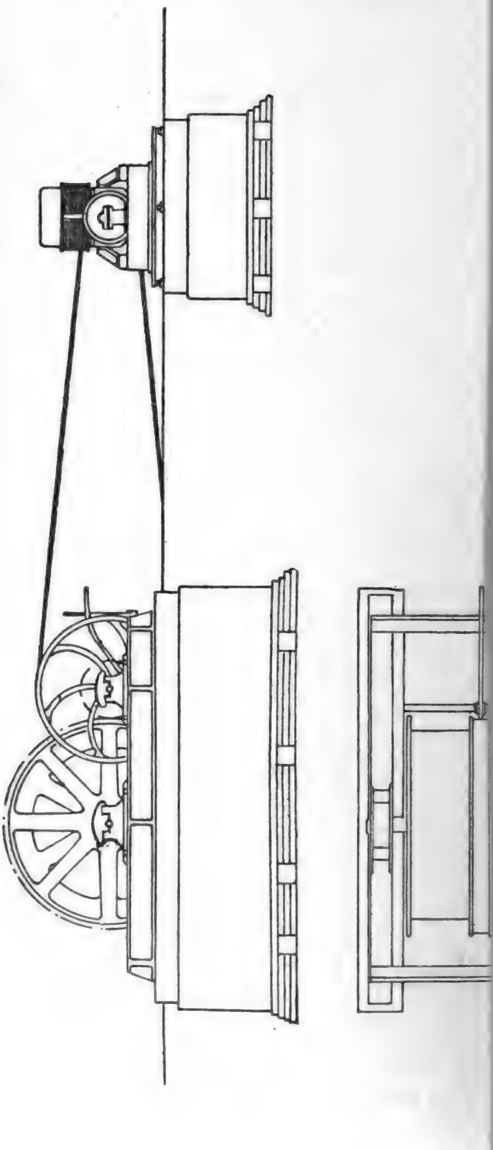
* Hughes, *A Text-Book of Coal Mining* (Griffin); Kerr, *Practical Coal Mining* (Griffin).



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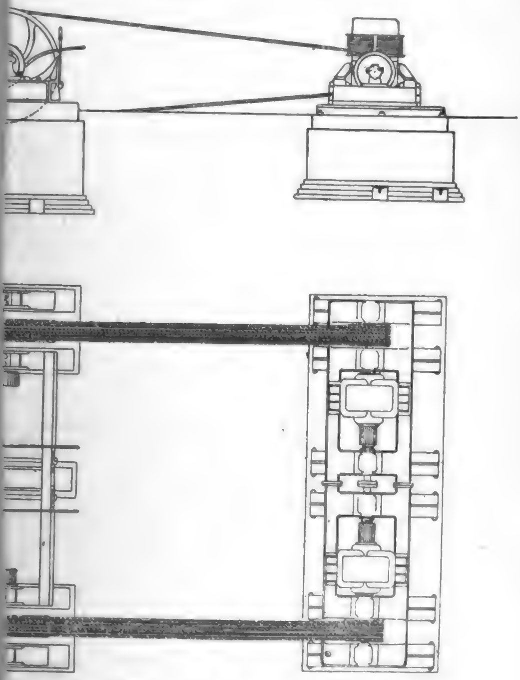

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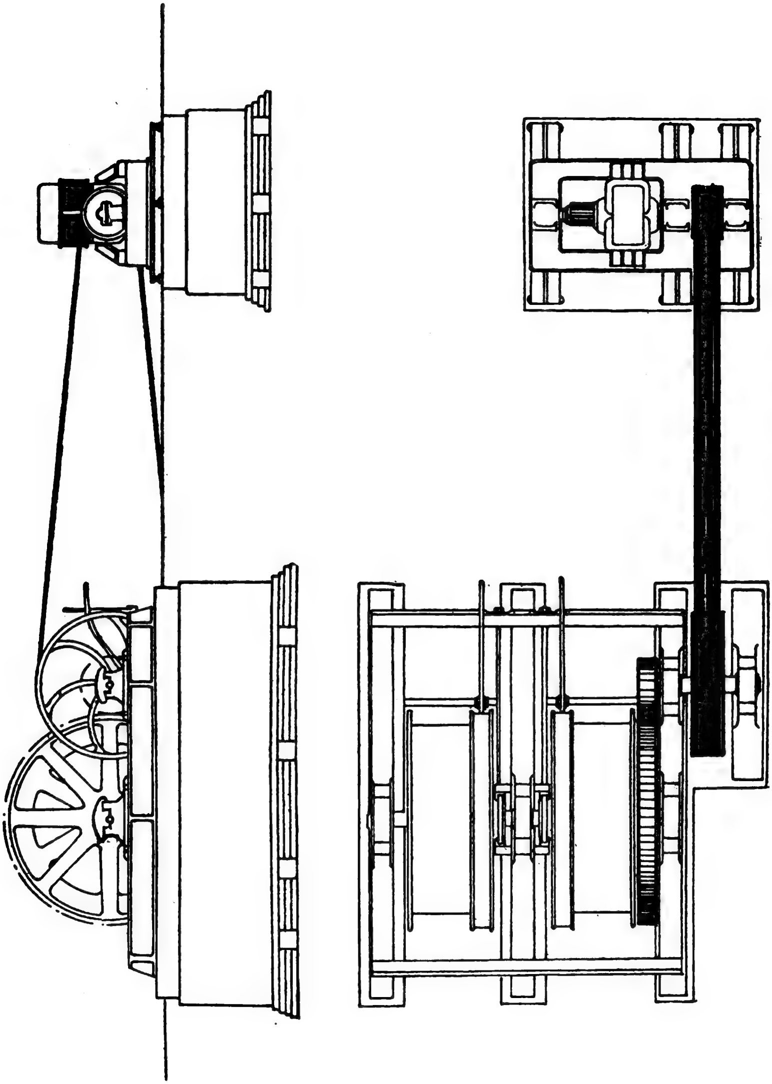

Fig. 90.—Main and Tail Rope Haulage.

$$\frac{60}{20} = 3 \text{ rakes per hour.}$$

$$\frac{400}{8} = 50 \text{ tons per hour.}$$

$$\frac{50}{3} = 16\tfrac{2}{3} \text{ tons per rake.}$$

Since each tub holds 10 cwts. this will mean 34 tubs per rake, and weight $= \frac{34 \times 14}{20} = 23$ tons 16 cwts., say 24 tons with couplings, &c.

To get the size and weight of rope the following empirical formulæ may be used—

$$C^2 \times 4 = \text{breaking load in tons for plough steel}$$

$$\text{and } C^2 \times \cdot 9 = \text{weight in lbs. per fathom,}$$

where C is the circumference of the rope.

$$\text{Then load} = \frac{24}{10} = 2{\cdot}4 \text{ tons.}$$

Taking a factor of safety of 6 and neglecting the weight of the rope—

$$C^2 = \frac{2{\cdot}4 \times 6}{4} = 3{\cdot}6$$

$$\text{and } C = 1{\cdot}89 \text{ inches,}$$

$$\text{Weight} = 3{\cdot}6 \times \cdot 9 = 3{\cdot}24, \text{ say } 3\tfrac{1}{4} \text{ lbs. per fathom.}$$

The tail rope might be rather lighter, but the difference may be neglected for calculation, as it would not affect the question to any appreciable extent.

Taking the friction of the ropes as $\frac{1}{20}$ of their weight, then

$$\text{Rope friction} = \frac{1600 \times 2 \times 3{\cdot}25}{2 \times 20} = 260 \text{ lbs.}$$

The tractive force that must be exerted will be that required to overcome the effect of gravitation upon the load, as well as that of friction of both load and rope. Since there are two ropes, and both have been considered of equal weight, they will balance each other and the effect of gravity on them may be neglected, then

Tractive force = friction of rake + friction of rope + effect of gravity on load.

Taking the frictional resistance to load at 32 lbs. per ton.

$$\text{Tractive force} = (24 \times 32) + \left(\frac{24 \times 2240}{10}\right) + 260 = 6422 \text{ lbs.}$$

The load is moved at the rate of 704 feet per minute.

$$\therefore \text{ Work done} = 6422 \times 704 = 4{,}521{,}088 \text{ ft.-lbs. per minute,}$$

$$\text{and H.P.} = \frac{4{,}521{,}088}{33{,}000} = 137.$$

The drum is 8 feet diameter, and travels $8 \times 3{\cdot}1416 = 25{\cdot}13$ feet at each revolution.

$$\text{Number of revolutions of drum per minute} = \frac{704}{25{\cdot}13} = 28.$$

Motor runs at 560 revolutions, and the gear must reduce the speed from 560 to 28, that is in the ratio of 20 to 1.

Summing up the results we have—

Three rakes per hour 34 tubs per rake. Plough steel rope 1·89 inches circumference, and weighing about 3¼ lbs. per fathom. Motor 137 B.H.P. geared 20 to 1.

The steepest inclination has been considered, and for that reason it would not be necessary to allow for friction of gear, as the motor would be working much under this power during the greater part of the run, and a slight overload when dealing with the rake on the steep part would do no harm.

The arrangement of a plant suitable for the above work is shown in Fig. 91. Here two motors coupled together, and driving by means of ropes upon each side, are used.

Endless rope haulage consists of a rope travelling round a double road, one line of rails being provided for conveying the empty tubs into the workings, another for bringing out the loaded ones. These two lines of rails may be arranged side by side in the one road, or where the roof is bad, and the keeping of a wide road would be a disadvantage, the rails may be made to occupy two separate parallel roadways, each of such a width as to contain only one line of rails. This provides a roadway for empties and another for loaded tubs, which in some cases may be a distinct advantage, as the distance apart may be anything required, and thus arrangements may be made for bringing all the loaded tubs in upon one side of a pit bottom or landing bench, and taking all the empties away from the other.

The tubs may be connected to the rope either singly or in rakes. When rakes are run they consist of a number of tubs coupled together, and attached to a clip bogie, which is worked by an attendant. This method is not so good as the single tub attachment as the delivery is intermittent and more labour is required to work it. On the other hand, the single tub system gives a regular delivery and requires less attendance.

The rope * is driven by a clip pulley, of which there are various types in use, the slack being taken up by a movable tension bogie. The C pulley, carrying two and a-half turns of rope on its circumference, is a very good driving pulley, as also

* For a full description see the works already referred to p. 143.

is that known as Thorncliffe's. Whatever form of pulley be used, it should be driven by a friction clutch, which will prevent the rope suffering from jerks, and undue strains, provided it is kept in good working order, a point not always attended to where such clutches are employed.

The rope may run at floor level and have the tubs attached by suitable catches, or it may be carried on the top of the tubs, the former method usually being preferred, especially if the road be worked round curves.

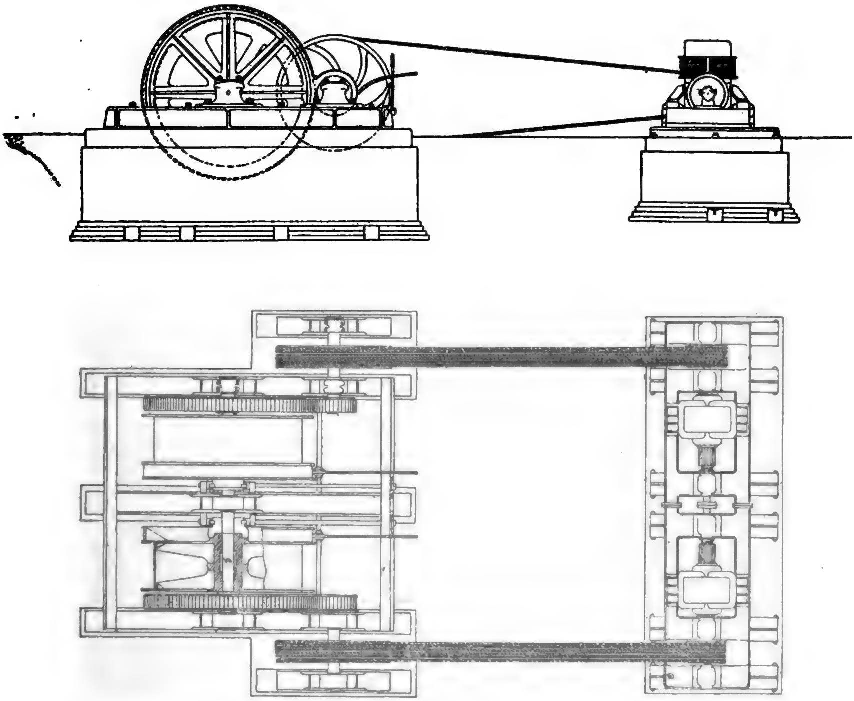

Fig. 91.—Main and Tail Rope Haulage.

The speed of the rope may be from $1\frac{1}{2}$ to 3 miles an hour, which is one feature of the success of this form of haulage. The cost of working is low, damage to plant is reduced to a minimum, and the ropes last for a considerable time. With single tubs the distance is of no consequence as far as cost of labour is concerned. With bogies and rakes, the cost will vary with the distance.

The size of motor required to work an endless rope haulage will, of course, be determined by the conditions, and the following example may be taken as illustrating a particular case :—

An output of 480 tons in 8 hours has to be drawn from an incline dipping 1 in 15, and 600 fathoms long. The tubs are 4 cwts. tare and 14 cwts. gross, the road is laid with bridge rails, and has to be worked by an endless rope running at two miles an hour. Find the size of motor to drive rope, if clip pulley be 7 feet diameter and speed of motor 520 revolutions per minute.

$$2 \text{ miles an hour} = \frac{2 \times 5280}{60} = 176 \text{ feet per minute.}$$

$$\frac{480}{8 \times 60} = 1 \text{ ton per minute} = 2 \text{ tubs per ton.}$$

$$\frac{176}{2} = 88 \text{ feet between tubs.}$$

$$600 \text{ fathoms} = 3600 \text{ feet, and } \frac{3600}{88} = 41 \text{ tubs on each side.}$$

41 tubs at 14 cwts. each = 28 tons 14 cwts.

To get size of rope, take working load as $\frac{30}{15}$ tons, and factor of safety at 5. Then for a crucible steel rope—

$$C^2 \times 2{\cdot}5 = 2 \times 5.$$
$$C^2 = 4.$$
$$\therefore \quad C = 2.$$

$C^2 \times {\cdot}9$ = weight per fathom in lbs. $= 4 \times {\cdot}9 = 3{\cdot}6$ lbs. per fathom.

Total length of rope is 1200 fathoms, and weight $= 1200 \times 3{\cdot}6 = 4320$ lbs.

$$\text{Friction of rope} = \frac{4320}{20} = 216 \text{ lbs.}$$

The tractive force necessary to move the load will be the sum of the friction of the rope, and both full and empty tubs, together with the effect of gravity upon the loaded tubs, diminished by the effect of gravity upon the empty tubs, or

$$T = F + G + f + \text{rope } f - g.$$

Where F = friction of loaded tubs.
G = gravity of loaded tubs.
f = friction of empty tubs.
rope f = friction of rope.
g = gravity of empty tubs.

Putting in these values—

$$T = 918{\cdot}4 + 4285{\cdot}8 + 262{\cdot}4 + 216 - 1224{\cdot}5 = 4458 \text{ lbs.}$$

The speed of the rope is 176 feet per minute, and the work done is $4458 \times 176 = 784{,}608$ ft.-lbs. per minute, and H.P. $= \frac{784{,}608}{33{,}000} = 23{\cdot}8$ nearly.

To this 25 per cent. may be added to give motor a margin for starting and to allow for friction of gear, giving 30 B.H.P. as the output of the motor.

The clip wheel is 7 feet diameter, and circumference = $7 \times 3{\cdot}1416 = 22$ say, and $\frac{176}{22} = 8$, the number of revolutions it must make per minute.

The motor speed is 520 revolutions per minute, and the gear must reduce this $\frac{520}{8} = 65$ to 1. The general arrangement of such a plant driven by spur gearing is shown in Fig. 92, which is reduced from working drawings of an endless rope haulage plant.

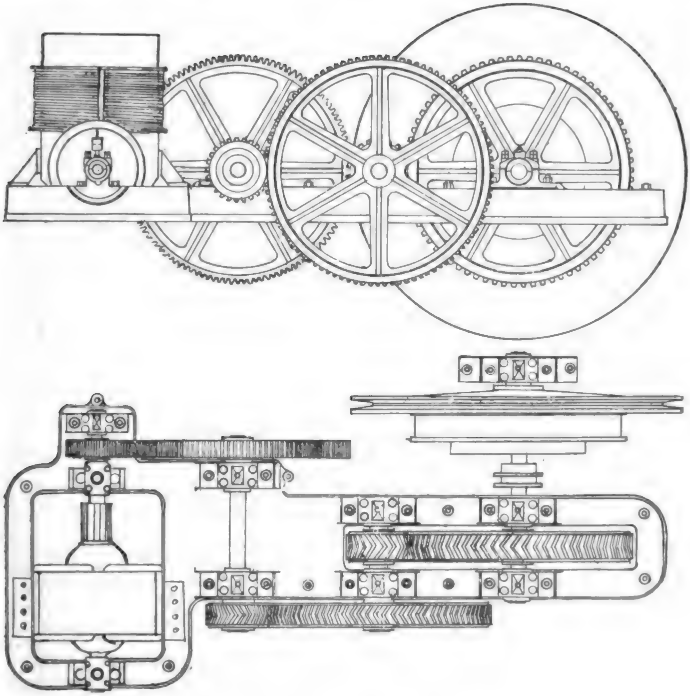

Fig. 92.—Endless Rope Haulage.

Taking the same conditions, and calculating for bogies and rakes being used instead of single tubs, the result will be as follows:—

Bogie, weight about 6 cwts.

$$\text{Bogie traction} = G + F = \frac{672}{15} + \frac{672}{70} = 54{\cdot}36 \text{ lbs.}$$

$$\text{One load tub } T = G + F = \frac{1568}{15} + \frac{1568}{70} = 126{\cdot}73 \text{ lbs.}$$

The clamp used by a haulage bogie can draw about 15 cwts. = 1680 lbs.

$$1680 - 54 = 1626 \text{ lbs. available to draw tubs.}$$

$$\frac{1626}{126} = 12 \text{ tubs per rake.}$$

$$\begin{aligned}\text{and total traction} &= \text{bogie 54 lbs.} + \text{12 tubs 1520 lbs.}\\ &= \text{1574 lbs. per rake.}\end{aligned}$$

Distance travelled each rake = 1200 fathoms = 2400 yards.

Two miles an hour = 3520 yards.

Then $\frac{2400 \times 60}{3520} = 41$ minutes per rake running; allow 4 minutes for changing, and time per rake becomes $41 + 4 = 45$ minutes.

Total tons to be dealt with is 480 in eight hours, and $\frac{480}{45} = 10\frac{2}{3}$, that is, 10 rakes per bogie per day. Each bogie draws 12 tubs, each containing 10 cwts. of coal, or a total load of 6 tons per rake, and $10 \times 6 = 60$ tons per day.

$$\frac{480}{60} = 8 \text{ bogies and attendants required to draw output.}$$

These bogies will not be equal distances apart, and to give average conditions 5 rakes may be assumed as the load coming up, with 2 going down, as the maximum, and the motor will have to be capable of dealing with this load.

$$T \text{ for 5 rakes} = 1574 \times 5 = 7870 \text{ lbs.}$$

$$T \text{ for 2 empty rakes} = f - g = (5{\cdot}8 \times 32) - \frac{12{,}096}{15\frac{1}{4}} = -620 \text{ lbs.*}$$

Taking a crucible steel rope, with 5 as the factor of safety—

$$C^2 \times 2{\cdot}5 = 3{\cdot}25 \times 5.$$

$$C^2 = 6\tfrac{1}{2}.$$

$$C = 2{\cdot}5 \text{ inches.}$$

$$\text{Weight per fathom} = 6{\cdot}5 \times {\cdot}9 = 5\tfrac{1}{2} \text{ lbs.}$$

$$\text{Total weight} = 1200 \times 5\tfrac{1}{2} = 6600 \text{ lbs.}$$

$$\text{Friction of rope} = \frac{6600}{20} = 330 \text{ lbs.}$$

$$\begin{aligned}\text{Total } T &= \text{traction of full tubs} + \text{rope friction} - \text{traction of empty tubs}\\ &= 7870 + 330 - 620\\ &= 7580.\end{aligned}$$

And work done = $7580 \times 176 = 1{,}334{,}080$ ft.-lbs. per minute.

$$\text{H.P.} = \frac{1{,}334{,}080}{33{,}000} = 40{\cdot}4 \text{ H.P.}$$

Adding 25 per cent., as in the last case, for friction of gear, &c., the actual output of the motor would require to be 50 H.P.

* The negative sign indicates that the force has to be applied to keep the tubs from running away down hill.

A comparison of the two cases shows that the single tub system requires less capital outlay for installation, and can be worked more cheaply afterwards, as two men and two boys could under ordinary circumstances deal with the output stated, whereas with bogies and rakes eight bogiemen would be required.

While haulage by endless rope is readily worked on flat or comparatively flat planes, it is quite possible to apply it to very steep grades, with no more trouble than would be occasioned by other forms under similar conditions. With undulating gradients the rope is best carried at the floor level, and under the tub the same applies where junctions and attaching places are numerous. In steep grades it is best to have the rope carried above the tubs and supported by hat pulleys, the tubs being attached by means of a chain 12 or 14 feet in length, with a hook at each end; one of these hooks is attached to the drawbar of the tub, the other end passed three or four times round the rope and secured by the hook, as shown in Fig. 93. Although

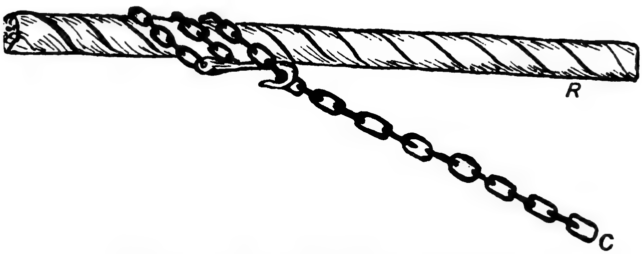

Fig. 93.—Tub attachment for Steep Grades.

R = Wire rope. | C = Chain attachment to tub.

this method is not so well adapted for attaching and detaching tubs as some of the others, there are none more secure in the matter of gripping power on the rope, a most essential feature on steep grades.

The endless-chain system * is exactly the same as the endless-rope system already described, but with a chain substituted for a wire rope; the speed may, in many cases, be rather less—from 1 to 2 miles an hour. The chain admits of a ready attachment of the tubs, and branches and curves can be very easily worked. By using bearing-up pulleys the tubs can be made self-detaching, and by a suitable arrangement of grades they can be made to gravitate past branches and attach themselves automatically.

* For details, see text-books on Coal Mining.

This system is not likely to be adopted in many cases for secondary haulage unless the system was that used all over the colliery, but electric driving might with advantage be adopted in most cases where the endless-chain system is used.

One objection to the use of a chain is the great weight in the shaft should the shafts be deep and the system applied to the main haulage. In such cases it is almost imperative that the driving power should be supplied at the pit bottom, and this condition at once opens up the way for the application of electricity with every chance of economy and success.

To illustrate the size of motor required to do a given amount of work the following example may be taken :—

An incline 400 fathoms in length dips 1 in 15 and is laid with bridge rails. An output of 500 tons has to be drawn in eight hours, the tub itself weighs 4 cwts. and holds 10 cwts. of coal. The speed of the chain is to be 2 miles an hour. If the drum be 4 feet diameter what H.P. must the motor give running at 560 revolutions per minute?

$$500 \text{ tons} = 1000 \text{ tubs.}$$

$$\frac{1000}{8} = 125 \text{ tubs per hour.}$$

$$\text{Speed} = 1760 \times 2 = 3520 \text{ yards per hour.}$$

$$\frac{3520}{125} = 28 \text{ yards between tubs.}$$

$$400 \text{ fathoms} = 800 \text{ yards and } \frac{800}{28} = 28 \text{ tubs on each side.}$$

$$28 \text{ tubs at } 14 \text{ cwts. each} = 43{,}904 \text{ lbs.}$$

Assume chain to weigh 23 lbs. per fathom, then $23 \times 400 = 9200$ lbs.
Total weight on load side $= 43{,}904 + 9200 = 53{,}104$ lbs.
28 tubs at 14 cwts. each = 12,544 lbs.
400 fathoms chain at 23 lbs. per fathom = 9200 lbs.
Total weight on empty side = 21,744 lbs.

To find the size of chain to carry the load safely the following empirical formula may be used :—

Let D = diameter of chain in sixteenths of an inch.
,, W = weight in lbs. per fathom $= D^2 \times {\cdot}21$.
,, B = breaking load in tons.

$$\text{Then } \frac{D^2}{9} = B.$$

Taking the factor of safety as $5\frac{1}{2}$ and the load as 2 tons (its real value is $\frac{53{,}104}{15} + \frac{53{,}104}{70} = 4298$ lbs.)

$$\frac{D^2}{9} = 2 \times 5\tfrac{1}{2}$$
$$= 11.$$

$$\therefore D = \sqrt{99} = \tfrac{10}{16} \text{ of an inch} = \tfrac{5}{8} \text{ inch.}$$

$$W = 99 \times {\cdot}21 = 20{\cdot}79 \text{ lbs. per fathom.}$$

The estimated weight was 23 lbs. per fathom. This is so near the calculated weight that no change is necessary, using the same values of the letters as in previous examples.

$$\begin{aligned} T &= F + G + f - g \\ &= \frac{53{,}104}{70} + \frac{53{,}104}{15} + \frac{21{,}744}{70} - \frac{21{,}744}{15} \\ &= 758 + 3540 + 310 - 1449. \\ &= 3159 \text{ lbs.} \end{aligned}$$

$$\text{Work done} = 3159 \times 176 = 555{,}984 \text{ ft.-lbs. per minute,}$$

$$\text{and H.P.} = \frac{555{,}984}{33{,}000} = 16{\cdot}8.$$

Add to this about 25 per cent. for friction of gear, &c., and the motor would require to give about 22 H.P. at the belt pulley.

NOTE.—It will be observed in the foregoing example that the friction of the chain is taken as $\frac{1}{70}$, the same as that of the tubs; this is because the chain would be carried on the top of the tubs.

Taking the driving-wheel diameter at 4 feet, the circumference is $4 \times 3{\cdot}1416$, and the number of revolutions per minute is $\frac{176}{4 \times 3{\cdot}1416} = 14$ approximately.

The motor runs at 560 revolutions per minute, which gives the gear as $\frac{560}{14}$, a reduction of 40 to 1.

In all the foregoing systems of haulage the application of electricity as a motive power is highly advantageous, especially in smoothness of starting and complete control over the speed, two important points in haulage. Reversal of the motor is also easily arranged for where required, and all conditions that are met by an ordinary steam or compressed air engine are equally well satisfied by the motor. This, added to the ease with which power can be transmitted electrically, makes the application of electricity, to secondary haulage at least, a matter for serious consideration by all colliery managers whose wish it is to keep their collieries well equipped with the best and most economical modern appliances.

Haulage by Locomotives is yet another form which has not come much into use in this country, although it has been adopted to a considerable extent in American mines, and also on the Continent. One of the chief reasons for this system not being taken up at home is the steep grades at which most of the coalfields lie. There are but few places where the workings would be flat enough to get even moderately satisfactory results, and for that reason alone it is not at all likely that haulage by locomotive, even with considerable advances in the use of electricity, will, at any time, be largely adopted in English and

Scottish collieries, at least for work underground. For moving waggons about sidings on the surface there is, however, a likelier field, and with this end in view some particulars regarding electric locomotives for use about mines will be given. For surface work, where the gradients are such as will suit a locomotive, the advantages over rope haulage are greater simplicity in working, and decreased cost of maintenance, due, largely, to the use of the locomotive only when required, and the reduction of friction. A wire rope would have to be kept running continuously, and the friction would be slightly greater than that of the locomotive.

Where adopted, the arrangements are usually the same as in the overhead tramway system, a bare wire being suspended from poles by suitable insulators, the current being taken from this wire by a trolley, and after doing work in passing through the driving motor of the locomotive being led to the tram rails, which form the return circuit. For mining purposes the locomotives are usually built of a size to suit the requirements, and the author is indebted to the British Thomson-Houston Company for the following details of one of their mining locomotives suitable for running at a speed of 8 miles an hour, and giving a tractive pull of 4500 lbs. The complete motor weighs about 13 tons, and is shown in Fig. 94.

The frame is of cast iron, heavy in structure, and so designed as to protect the motor and gear. Each frame consists of two heavy side castings and two end pieces. The joints are machined and the sections held together by heavy bolts, giving the whole structure the rigidity of a solid casting.

The end frames form the bumpers, and are provided with draw hooks to suit the requirements of the conditions under which they are to be used. The frame is arranged to run as close to the rails as is consistent with proper clearance, thus preventing any obstruction on the track from injuring the gear. The working parts of the locomotive are made as light as is consistent with strength, and the extra weight required for tractive purposes is supplied by the frame, which is supported on springs. The axle boxes are of the standard railway type, with removable brass linings. The wheels are of standard form, having chilled iron treads, this type having been proved by experience to give the longest life with the minimum wear and tear. The brake is so designed that in whatever position it is left it is locked, that is whether the shoes are on or off. The locomotive is fitted with two pairs of sand boxes and also with a trolley, which is the collector gear, by means of which the motors are supplied with current from the overhead line, the

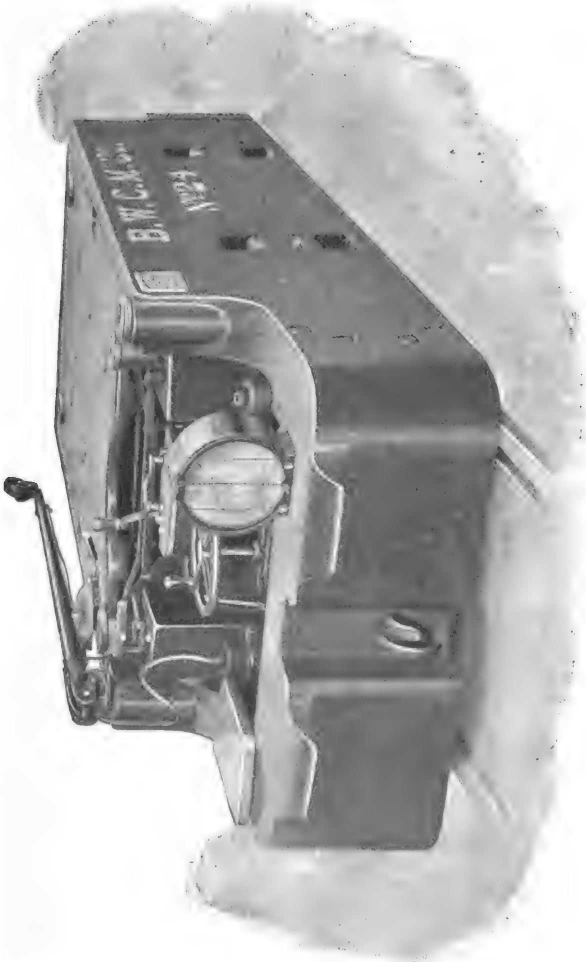

Fig. 94.—British Thomson-Houston Electric Locomotive.

wheels forming the other connection and the rails the return conductor. The trolley consists of a swivelled wheel carried on an insulated pole, which is mounted on a swivelled base, so that on whichever side of the locomotive the trolley wire is suspended, the same trolley is available for collecting the power,

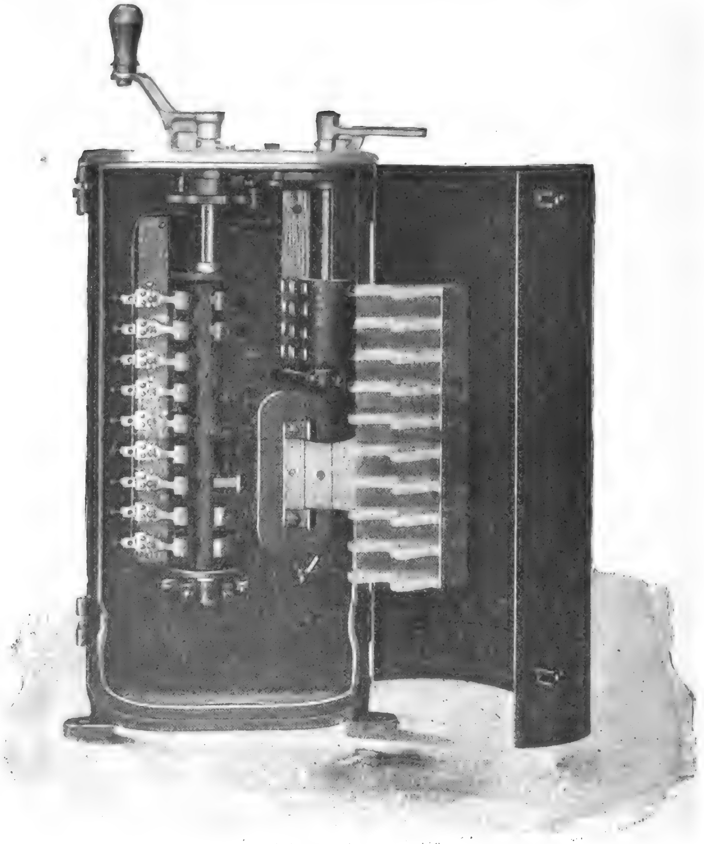

Fig. 95.—Magnetic Blow-out Controller.

and the swivelled head enables the trolley to negotiate curves and to adjust its position automatically to the alignment of the track. The wheel is maintained in contact with the trolley wire by means of a compressed spiral spring, the arrangement

being such that the upward pressure against the wire is practically uniform through the limits of vertical variation. The trolley is so designed that the operator can reverse it without leaving his place. The motor is controlled by a magnetic blow-out controller (Fig. 95), which is so designed that when opening the circuits in stopping, or varying the speed, no racing, and consequent destruction of the electrical contacts takes place. The reversing switch is interlocked with the main controller in such a manner as to prevent any possibility of the motors being reversed, unless the current is entirely cut off, nor can the motors be connected to the circuit unless the reversing switch is in its proper position. In connection with this controller a sufficient amount of resistance is used to enable the locomotive to be started smoothly and to run at variable speeds.

The type of motor used for driving is shown in Fig. 96. The

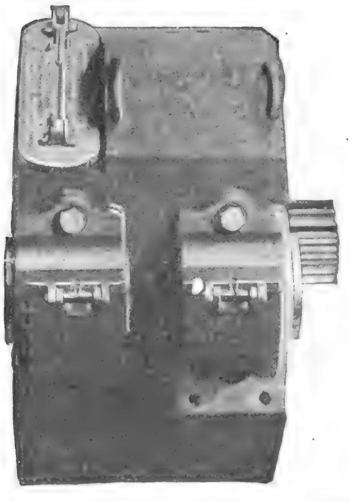

Fig. 96.—Enclosed Motor for Locomotive.

locomotive is usually fitted with two sets of driving wheels, and two motors of the type shown are fitted to gear with the axles, one motor to each axle. This motor is shown opened out in Fig. 97, which gives a general idea of the arrangement of the armature, and the construction of the field frame, which admits of the armature being readily inspected and changed, if necessary, the field frame being made in halves and hinged. The bearings for the second motion shaft are cast as part of the field

frame, thus rendering the motor and its gear most compact in design. The gears are of cut steel and are enclosed in a malleable wrought-iron gear case. The motors are suspended by springs from the side frames of the locomotive, and, as only a portion of the weight of each motor is carried by the axle, the strains and jars, due to a rough track, are reduced to a minimum.

The motors are arranged in the centre of the locomotive and turned towards each other between the axles, as this arrange-

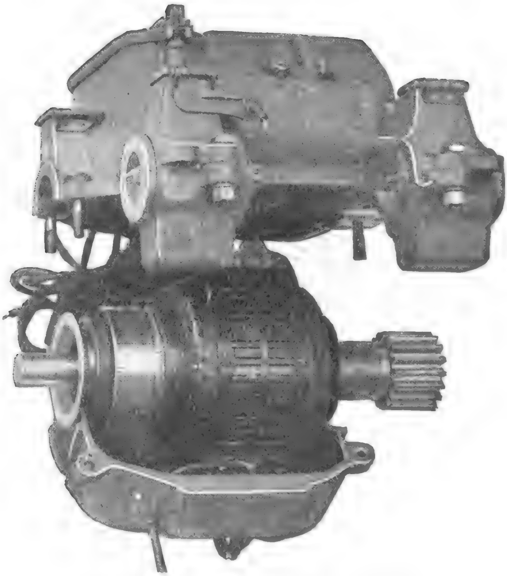

Fig. 97.—Locomotive Motor (open).

ment eliminates any tendency of the locomotive to rock when running at high speeds on a rough track. In addition, the locomotives are equipped with electric headlights, gongs, fuse boxes, and all the necessary fittings.

The number of tons that a locomotive will be able to pull will depend on the gradient and on the general condition of the track. The following may be taken as an example of calculating loads :—

An electric locomotive has a draw-bar pull of 2400 lbs., how many tons will it be able to pull on a road rising 1 in 50 if friction be taken as 32 lbs. per ton of load?

$$\text{Work done against gravity} = \frac{2240}{50} = 45 \text{ lbs. per ton.}$$

$$\text{Friction} = 32 \text{ lbs. per ton.}$$

$$\therefore \quad \text{Total work} = 45 + 32 = 77 \text{ lbs. per ton of load.}$$

Total available pull is 2400 lbs.

$$\therefore \quad \text{Number of tons of load} = \frac{2400}{77} = 31.$$

The above example neglects the weight of the locomotive, but, as in most cases, the draw-bar pull would be given for a dead level track, the weight would have to be taken into account whenever the load had to be dealt with on a gradient.

Thus a mine locomotive weighing 13 tons, and having a draw-bar pull of 4500 lbs. on the level, has to run on an inclination of 1 in 20. What load will it be able to draw up this incline if friction be taken as $\frac{1}{70}$?

$$\text{Pull lost in raising locomotive up incline} = \frac{13 \times 2240}{20} = 1456 \text{ lbs.}$$

$$\text{Available pull for dealing with load} = (4500 - 1456) = 3044 \text{ lbs.}$$

$$\text{Traction for load} = \frac{2240}{20} = 112 \text{ lbs. per ton against gravity.}$$

$$\text{Total traction} = 112 + 32 = 144 \text{ lbs. per ton of load.}$$

$$\text{Total load} = \frac{3044}{144} = 21 \cdot 1 \text{ tons.}$$

The rails used should be of sufficient weight to give rigidity to the way, and might be from 25 lbs. per yard with 6-ton locomotives to 50 lbs. per yard with those of about 15 tons, the weight being varied to suit that of the locomotive adopted.

Trolley wires are put up in much the same manner as for ordinary tramway work, but instead of soldering the wire to the insulator it is best clamped, the insulators will be fastened to the props and bars where possible, and, in some cases, they may be bolted to a dug let into the roof. Protection will be best afforded by having a separate roadway for the men going backwards and forwards, as otherwise there is a chance of accidents, especially where the height of the road is low and necessitates the keeping of the trolley wire within reach of persons passing along the roadway. The rails which form the return circuit should be joined by copper bonds, and if water pipes run near the rails copper connections should be made between them and the rails at frequent intervals, as this serves to preserve them from destruction by electrolysis.

Another locomotive much used for mine haulage in America is the Jeffrey, which is shown in Fig. 98. Its construction is much the same as that already described. Various types are made to suit different conditions; the one shown is the Gondola type, and has the gear and seat for the driver all at the one end.

Where these locomotives are used in very low seams, they may be driven by means of a storage battery. This does away with the use of trolley wires, which are, to say the least, objectionable under any circumstances. A locomotive of this

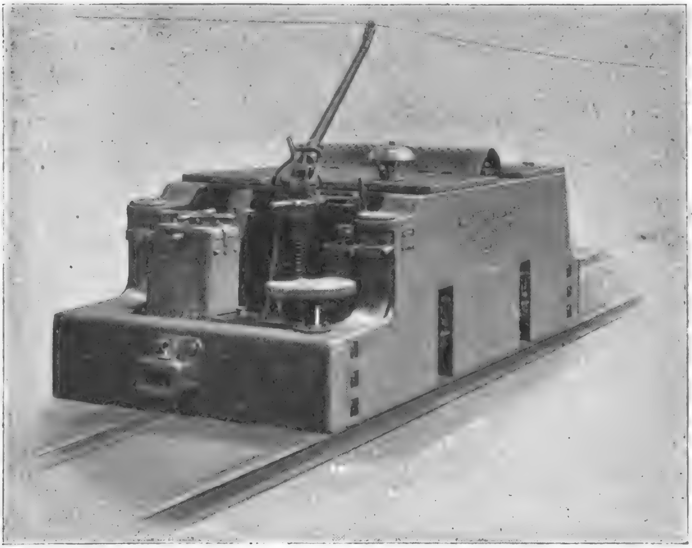

Fig. 98.—Jeffrey Electric Locomotive.

type is shown in Fig. 99; the storage battery is carried behind on a separate truck.

In this particular case the locomotive was designed for lifting coal from the face, the secondary battery supplying the power. When on the main road the trolley pole, which is also fitted, can be used, the storage battery being used only where the roads are too low to carry bare wires.

Polyphase motors are also being used for haulage as well as for all other branches of colliery work, and good results are being obtained. Plants for haulage and other purposes are at

work at Sandwell Park Colliery, Garswood, and Cadeby Main, all upon the three-phase system. These plants, as well as others of the same type that have lately been put down, will

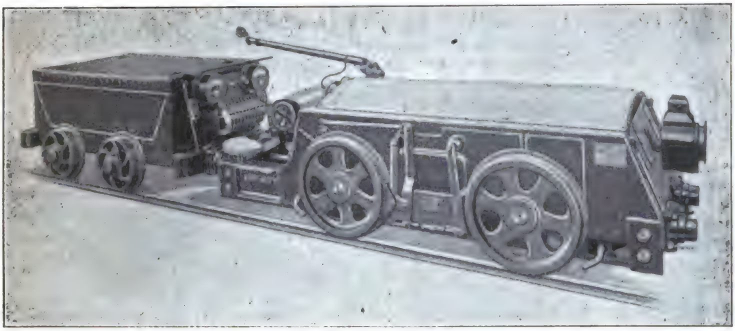

Fig. 99.—Jeffrey Mine Locomotive and Storage Battery.

have their working watched with interest, as many firms will doubtless be inclined to see how they operate over a continued period, before they fix upon the system they themselves will adopt for similar purposes.

EXAMPLES.

1. A compressed air engine giving 5 H.P. is used for underground haulage, it is to be replaced by an electric motor. Taking the efficiency of the motor as 75 per cent., what current will be required if the E.M.F. is 380 volts?—*Ans.* About 13 amperes.

2. A motor has to drag a rake of 10 tubs, weighing 1 ton gross each, up an incline of 1 in 10 at a speed of 8 miles an hour, what tractive force must it exert? What H.P. does this represent? Neglect weight of rope.—*Ans.* 2560 lbs. tractive force; 54·6 H.P.

3. What size of motor would you erect to draw a rake of 12 tubs from a dook 500 fathoms long, dip 1 in 5, gross weight of tub 14 cwts., tare 4 cwts.? State size of rope you would use. Assume drum to be $7\frac{1}{2}$ feet in diameter and maximum speed of rake 8 miles an hour.—*Ans.* Motor 94 H.P. at 480 revolutions per minute, geared 16 to 1; rope, crucible steel, about 4 lbs. per fathom and $\frac{3}{4}$ inch diameter.

4. An electric locomotive has a draw-bar pull of 3000 lbs. How many tons will it be able to pull on a road rising 1 in 70? Take friction as 32 lbs. per ton and neglect weight of the locomotive.—*Ans.* 47 tons nearly.

5. A mine locomotive has a draw-bar pull of 4500 lbs. on the level, its own weight is 13 tons. What load, including its own weight, will it draw up an incline of 1 in 40 taking friction as 32 lbs. per ton?—*Ans.* 42·8 tons.

6. An output of 240 tons of coal has to be drawn in eight hours from a dook 300 fathoms long dipping 1 in 10. The tubs weigh 14 cwts. full and 4 cwts. empty. The rope is 2 lbs. per fathom and the drum 7 feet diameter. Find the H.P. of motor to do the above work, taking its efficiency as 90 per cent., and speed 640 revolutions per minute. The average speed of the rake has to be 8 miles an hour, and the maximum speed 10 miles an hour.—*Ans.* A 56 H.P. motor; geared 16 to 1.

7. An output of 500 tons of coal per day of eight hours has to be drawn by means of an endless rope from a road 300 fathoms long, dipping 1 in 20. The tub holds 10 cwts. of coal and weighs 4 cwts. when empty. The speed of the rope is to be 2 miles an hour, and the diameter of the driving pulley is 7 feet. Find the H.P. of motor required for this work if efficiency be 70 per cent. State the required reduction of speed if motor runs at 560 revolutions per minute.—*Ans.* 15 H.P.; gearing 70 to 1.

8. An output of 400 tons of coal per day of eight hours has to be drawn from a road 300 fathoms long, with a dip of 1 in 10, by means of an endless chain. The tub is 14 cwts. gross and 4 cwts. tare; the speed of the chain is $1\frac{1}{2}$ miles an hour, and the drum is 4 feet in diameter. Taking friction at 32 lbs. per ton, find the H.P. of motor required; if efficiency of motor and gear be 75 per cent. State also the gearing required, if speed of motor be 600 revolutions per minute.—*Ans.* Motor, 30 H.P.; chain, $\frac{5}{8}$ inch diameter; gearing, to reduce speed of motor, 60 to 1.

CHAPTER VIII.

COAL CUTTING.

THE question of working coal by mechanical methods is one that grows in importance as time advances, and this for two reasons—in the first place, there is the growing difficulty of labour to contend with; and, in the second, the necessity for working many of our thin seams on account of the exhaustion of those of greater thickness. The latter reason is a most important one, for little by little the best seams will be worked out, and, if supply has to keep pace with demand, the thinner seams must be attacked. To do this successfully the coal produced from those seams must compete against that raised from the thicker ones, for some time at least, and it becomes necessary to do everything possible to keep down the cost of production, at the same time using every possible means to keep the coal in such a state as will command the highest market value.

In many of our coalfields, and notably those in Scotland, shafts have been sunk and equipped for working the thicker seams, and now with those seams worked out, or nearly so, in some cases the owners of those collieries have to choose between stopping them altogether and removing their plant, or sinking further when necessary, and commencing to work some of the thinner seams. The capital expenditure on plant has probably been redeemed while working the thicker seams, and all the colliery owner has to look to in such a case is whether he can work the thinner seams at all without losing money, because if such a course is possible it will be to his interest to keep the pit on. This feature of the question certainly enables some thin seams to be worked, which could not possibly have been done under ordinary circumstances, and where such conditions exist every effort should be made to work those thinner seams if at all possible. The colliery owner will, under such circumstances, do well to turn his attention to the question of mechanical production, as, undoubtedly, it offers a solution to the problem.

Coal cutting by machinery has its advantages and disadvantages, but there is little doubt that the latter are far outweighed by the former, and that coal cutting will receive much greater attention in the immediate future than it has in the past.

Throughout Britain at the present time only a very small proportion of the coal produced is under-cut by machinery, and it may be noted that the bulk of our coal seams are comparatively thin, 6 feet and under, whereas in America, although the seams worked are of greater thickness, 25 per cent. of that country's production is under-cut by machinery. Until a short time ago we were the largest coal-producing country in the world, now America occupies that position, and has been assisted to the premier place by the extensive use of coal-cutting machinery.

As a rule, the holing or under-cutting of any seam could be performed by machinery at a cheaper rate than hand labour; hence in seams, where under-cutting represents the greater portion of the work, the adoption of machinery is the more likely to be accompanied with success. Since for a given weight of coal the area to be under-cut will vary as the thickness, should other conditions be the same, mechanical under-cutting will be the most successful in the thinner seams; and in practice we find, with a few exceptions on account of hardness, nature of roof, and so on, that this is realised.

The more rapid motion of the face of the coal has a tendency to keep the roof in the best condition. This diminishes the number of accidents from falls of roof, and may at the same time effect a considerable saving in the amount of timber used as compared with hand labour.

Another and most important point is the increased amount of round coal obtained from the seam when cut by machinery as compared with hand, which may vary from 5 to 30 per cent. according to conditions, and which, in the majority of cases, represents an increase in the selling price of the coal taken as a whole. The only case where the size of the coal obtained is not of any importance is that where the coal is to be used for the purpose of making coke. The accompanying sketches (Figs. 100 and 101) will show, to some extent, how the decreased quantity of small results from the use of machinery for holing. There is also a further condition attached to the bringing down of the coal. When under-cut by hand the depth is not so great (on the average about 1 foot less), and, in addition, the coal is cut away to a greater extent at the front, both of those conditions tending to prevent the coal from breaking down as readily as when under-cut by machinery. When the seams lie at some depth from the surface the weight or pressure upon the coal is likely to be considerable. This may prove either an advantage or a disadvantage in either of the systems when compared with the other. When the coal breaks down by itself without blasting that is all that is required; should the weight of the overhanging

mass, together with the pressure from the roof be, however, unable to effect this when the coal is under-cut by hand, then the chances are that with machine under-cutting it would take place, blasting or wedging being thus dispensed with, and the breakage of coal into small, which attends those operations, also avoided. On the other hand, should the pressure be such as to cause this in any case, a little extra trouble may arise in the case of under-cutting by machinery, owing to the precautions that have to be taken to sprag the coal, so as to prevent it falling upon the machine, and thus causing loss of time.

Another feature in favour of mechanical coal cutting is that fewer men are required for a given output, which, in some cases, would be a distinct advantage, as the money that would be

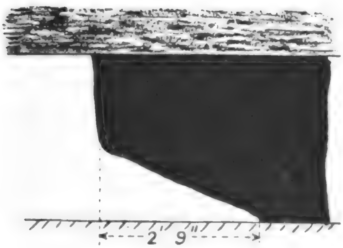

Fig. 100.—Hand-cut Coal.

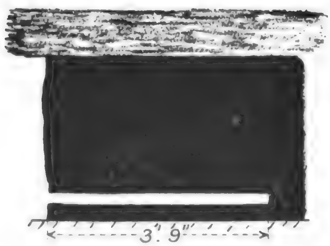

Fig. 101.—Machine-cut Coal.

saved in providing houses for the workmen might cover a considerable part of the capital expenditure upon machinery.

There are also further directions in which cost ought to be reduced by the adoption of machinery :—

1. By cutting the coal at a cheaper rate.
2. By reducing the cost of upkeep of roads on account of less length of face required for a given output, as compared with that necessary to obtain the same output by hand labour.
3. By decreasing the amount of timber, rails, sleepers, &c., required in the roads.
4. By reducing the breakage of coal to a minimum, and thus enhancing the selling price of the coal as a whole.

Regarding the other side of the question, there is the larger amount of capital expenditure which, in the event of bad trade or forced stoppage, would be lying idle, either in part or whole. Again, seams with a very steep inclination, or having a bad roof, are not well suited for coal cutting, and if adopted under such circumstances considerable trouble may arise. There is also the further question of trained men to work the machines, but this

may easily be left to the manager, who should have no difficulty in providing and retaining a staff adequate for coping with all emergencies.

Once the adoption of coal-cutting machinery has been decided on, the next question that comes up for settlement is where the cutting has to be done, whether in the coal itself or in any bands of fireclay that may be contained in the seam, or if it should be done in the floor or pavement of the seam. If cutting be done in the coal, the percentage of small coal will then be at a maximum for machine cutting, while at the same time the length and depth of face under-cut will be large, but the seam will require to be of a height of not less than about 20 inches. Should the height of the seam be less than this, then cutting would have to be done in the floor in order to get headroom; but the author is strongly of opinion that many seams, with heights up to even 3 feet, could with advantage be holed in the floor. For such work it is necessary to use a machine which will cut its own floor, a point which will be noticed when discussing the various types of coal-cutting machines. Should a band of fireclay occur in the seam, then it will, in most places, be advisable to do the holing in this band. Should machines which do not cut their own floor be used, then the coal or clay left standing above the floor level, at which the machine runs, must be lifted after holing, and before the road is laid down for the machine making the next cut; this entails extra labour, and means a further breakage of coal (if it be coal that is left), both of which tend to increase the cost. On the other hand, more power is required to cut under the level of the rail, as the machine does not free itself so completely as when the cut is made a few inches or more above floor level.

The rate of cutting varies with the conditions of the seam, and the class of machine used, as well as with the nature of the material in which the cutters work, and at the same time with the power available for driving the machines, and may be anything from 50 to 180 yards per shift of eight hours to a depth of from 3 feet to 3 feet 9 inches. It is, as a rule, better to cut rather deeper than to travel over too great a distance, as this proceeding saves time in shifting the machine, and requires less roadlaying. The amount of coal obtained from a day's cutting of a machine will depend entirely on the distance and depth cut, together with the thickness of the seam. In cutting coal seams of 4 feet and over, it seems to be the practice to cut to a depth of at least 5 feet 6 inches, and in some cases even more; in such a case the length travelled does not require to be great.

While coal-cutting machinery can be applied to any of the systems of working coal we have but few cases of its application,

in this country at least, to systems of working other than that known as longwall, where a considerable length of face may be open for the machine to travel along; the longer the length of such face available without obstruction the greater the chances of doing good work. It will thus be seen that a clean field is much better suited for mechanical coal cutting than one which may be much broken up by faults.

Two systems of cutting are adopted. In one, the machine is made to travel continuously round a length of face from end to end; after cutting the whole length of face the machine is removed on a bogie to the starting point (this operation being usually termed flitting the machine) and cutting again resumed. The other method is to deal with a shorter length of face, and cut backwards and forwards along its length. While both systems have advantages the former is, perhaps, on the whole, the better, as one machine can be started behind the other at the necessary intervals, and there is no waiting at the end of the face until the last-cut coal has been removed, as is necessary if the latter be the one adopted. This is an obvious advantage in places where the winding of coal may be suspended for short intervals daily, during periods of dull trade or for want of waggons to load on, a source of much too frequent complaint at many of the Scotch collieries.

Where coal cutting by machinery is contemplated, the workings should be laid off in such a manner as to provide the utmost facilities for the machines. With steep inclinations it will be found better to cut to the dip and rise, rather than across the level course, on account of the greater ease with which the road for the machine can be kept. Where the inclination is flat this is of little consequence, and cutting may be performed with equal ease in any direction.

One method of arrangement for a flat seam is shown in Fig. 102, the cutting being carried on continuously round the coal face from the level upon the one side to that upon the other, the machine being then loaded up on a bogie and flitted along the level back to the original starting point. In the dook cutting would be done down the one side and up the other. In providing a starting place for the machine a hole may be cut square into the coal by hand large enough to admit the disc, or, if a start is made from a winning-out place, such as the level, the place may be kept far enough forward to let the machine open up its own cut. This can often be readily carried out by keeping the low or dip side building or pack well forward, and leaving as wide a space as safety will admit of on the rise side. The machine can thus be brought close into the face, where it starts

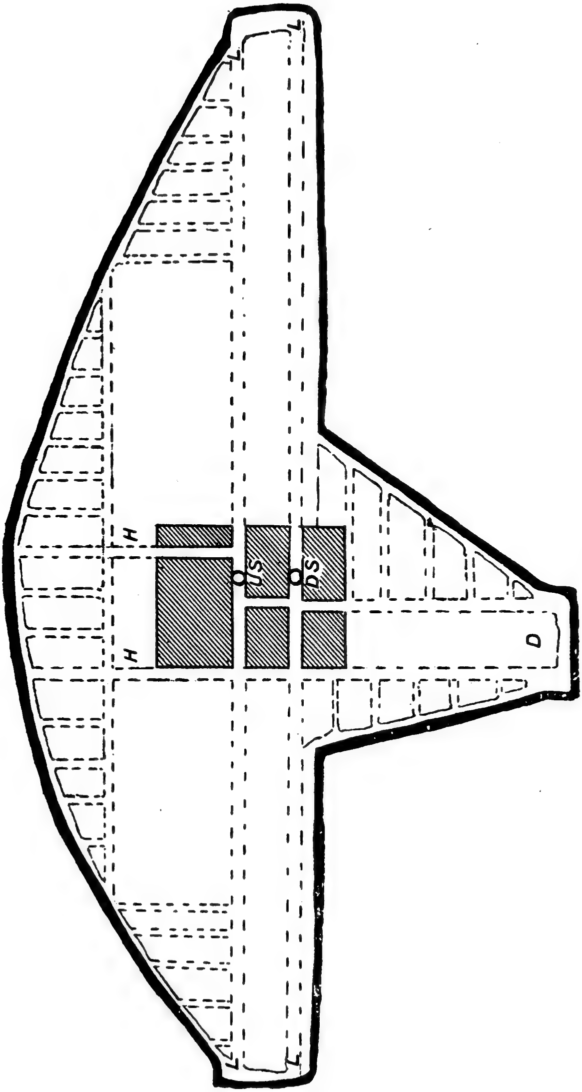

Fig. 102.—Longwall Opening-out for Machine.

H H = Main headings. L L = Levels.

D = Dook.

to cut just hehind the nose, gradually eating in as it goes forward. Fig. 103 will give an idea of the appearance of such a place for starting the machine from. In passing round curves with the machine they ought to be made as easy as possible, but curves of fairly short radius can be negotiated if care is taken to keep the machine well bridled, at the same time letting the rails skid if found necessary.

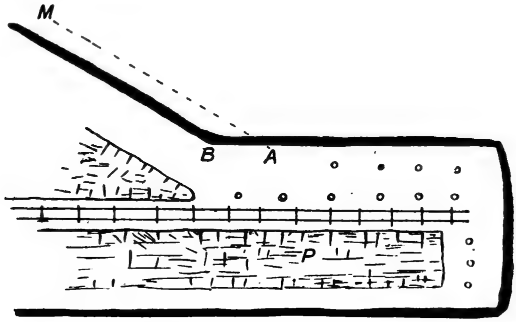

Fig. 103.—Opening Machine Cut.

A = Starting place for machine.
B = Full cut begins.
A M = Back of holing.
P = Pack walls or buildings.

Another method of laying off workings to suit coal cutters is shown in Fig. 104. This is the system adopted at Altofts Colliery, Normanton. The coal is worked on the panel system, and brought from the boundary home; this has the advantage of having all the roads passing through solid ground, and causes them to be kept up cheaper than if they were carried through waste. A central heading, A B, is driven, and the coal worked from that downwards, until it reaches a specified distance from the main roads, that part being then stopped, and the upper portion from the central heading carried back towards the other side of the panel. The lower part is shown as completed, while the upper part has the face extending from C to D, the coal being conveyed back through the roads between the pillars to the main roads, M R.

This system of working offers advantages under its own particular circumstances, and it may be said generally that the same statement applies to most seams, and that no rule can be given as to what the best method may be unless all the circumstances of the particular case are known. Although workings have to be specially laid out for machine cutting it is always possible to arrange old mines for the use of such machinery, and

although in some cases such a proceeding might be very difficult to carry out, in other cases the changes involved might only be trifling, as much depends on the system of working in vogue and upon the time the seam has been worked.

Transmission of power to the machines may be accomplished by compressed air, or by electricity; and of the two methods electricity is the one that is best adapted for this particular purpose. As compared with compressed air the first cost of plant is less, the future working costs less, on account of the

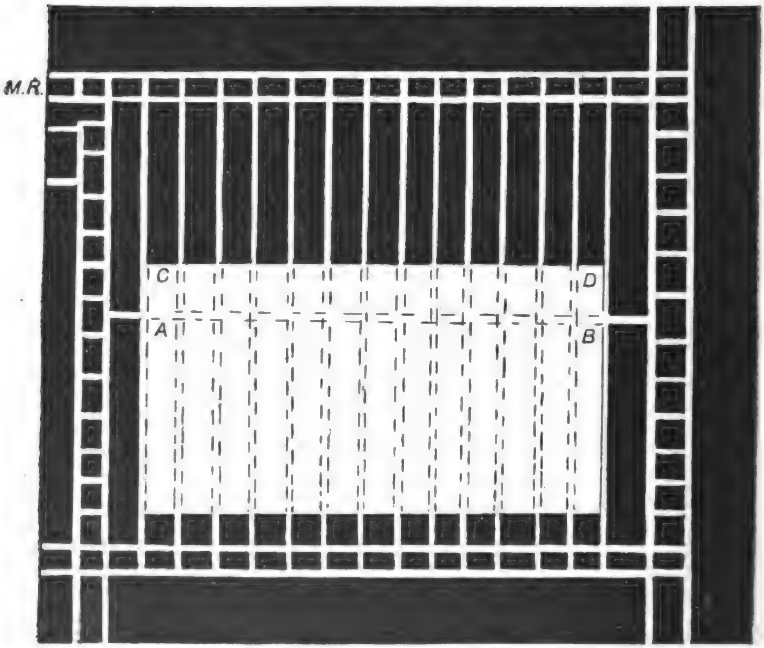

Fig. 104.—Panel Working.

higher efficiency of the electric transmission, and little or no trouble is encountered while moving from place to place. While compressed air may be used with an efficiency of from 25 to 40 per cent., electricity will give from 55 to 65 per cent., and that within reasonable limits of first cost. By using heavy cables and costly machines the efficiency could be increased to a considerable extent, but it is questionable if the gain thus effected would compensate for the increased capital outlay; and for that

reason only the approximate efficiency of ordinary everyday coal-cutting plant has been instanced.

Another important factor is that for a given space an electric motor will generate more power than any other class of machine capable of being put into the same space, and consequently more power is available for a given size of machine when electricity is adopted as the motive power. Against this there is the danger of sparking at the brushes or of damage to the cable igniting gases; both these sources of danger can be obviated by the means already explained. Besides this, it may be noted, that there are but few mines which contain explosive mixtures of gas and air travelling along the working face, and in the event of quantities having to be cleared away from any point, so that the air might be temporarily explosive, the machine could be stopped.

It is often urged against electrical machinery that it is fragile, and on that account easily damaged. That, under certain circumstances, damage is somewhat readily sustained the author must admit, but such damage is due, in nine cases out of every ten, to ignorance or carelessness on the part of the person in charge, and not to the defective construction of the machine. Take, for instance, the case of a coal-cutting machine, which has been made to bury its cutting wheel up to the frame, in passing through a nose on the face; if the machine is driven by compressed air, and if it cannot cut its way through, the engines will simply stick and no damage will ensue. On the other hand, should the machine be driven by a series wound motor current will be taken in proportion to the work done, and the machine will either be driven through the obstruction or the motor armature will be burnt out unless the fuse protecting the circuit gives way. The author has known more than one instance where, to save trouble in cutting through ground of variable resistance, and where fuses were burst pretty often, the person in charge has inserted larger fuses, and even in some cases put in a piece of copper wire of the same gauge as the lead fuse, with the result that the current rose beyond the carrying capacity of the wires on the motor armature and caused it to be burnt out. Such occurrences are, as a rule, laid to the charge of the machinery, and have done much to hinder the more rapid extension of electricity for the purpose of supplying power for cutting coal.

The power required to drive machines will vary with the speed of cutting, depth of cut, nature of the material being cut, and the condition of the seam, and may be anything from 10 to 50 H.P. Ample power should be provided, and machines

should be fitted with motors of from 25 to 30 H.P., which will run continuously under full load without injurious heating, and will take an additional load of at least 50 per cent. above their normal for short periods. There is little doubt that this is the key to the whole question as past experience shows, for with the earlier attempts to drive coal-cutting machines by electricity little but failure was the result, this being, in many cases, due to the mistaken idea that a motor of about 12 H.P. was ample for the purpose. All the modern machines that have been successfully applied have been fitted with motors of about twice that power, and the tendency of the best makers is still to increase the power, when this can be done, without altering the general design of their machine. Some machines—*e.g.*, the Clarke & Steavenson cutter—are now fitted with motors which can give 30 H.P. at normal load, and which may give twice that power for a minute or two, should an increase of load render it necessary. The power actually required will vary to a considerable extent within very short periods, the greatest variation being found in cases where the cutting is done below the level of the rail, and where the material being cut has any tendency to break out in small blocks before the cutters, as such pieces frequently get jammed between the revolving disc and the solid pavement below, or the coal above, and have to be crushed through, extra power being required. For this reason it is of importance to allow ample power for driving these machines, so that should any extra demand be made it will be immediately met with, and generators should be provided accordingly. The author's opinion is that for one machine a generator of about 50 H.P. should be used, with two machines a generator of about 80 H.P., and with three machines a 110 H.P. generator; for a greater number of machines the surplus power of the generator over the aggregate of that of the motors might still be diminished a little, but would have to be kept sufficient to feed all the machines working together at normal load, although the greater the number of machines provided, the less likelihood there will be of the whole of them being at work smultaneously. Machines are of different types, those best suited for electrical driving being—

1. **The Bar Machine,**
2. **The Disc Machine,**
3. **The Chain Machine,**

each of these having its special advantage under various conditions.

Bar Machine.—The first-named type of machines is fitted with

a tapered steel bar, which is attached to a socket carried on the frame of the machine. The bar is driven by means of a motor, which is geared in the usual way. Steel-cutters are fixed at intervals along the bar, which has a spiral thread cut upon it, these cutters being placed either on or between the threads, according to the width of holing required. A rectangular frame carries the motor, the haulage drum and ratchet gear for feeding, together with the necessary motor starting resistance, and other small details, the whole being mounted upon four wheels of small diameter fitted with double flanges. The speed of the bar is from 300 to 500 revolutions per minute, and in some types a slight reciprocating motion is also imparted to it. It is claimed for this type of machine that the high speed of the cutter bar reduces the gear required to a minimum when electricity is employed, and as far as the author is aware this class of machine, as it exists at present, is only used with electricity as the motive power. The best known British machine of this class is the **Hurd**, made by Messrs. Mavor & Coulson, Glasgow. Three sizes are adopted, so as to suit the various requirements of different seams. The small size has a height of 14½ inches, including the rails upon which it runs, the width is 2 feet, and the length over all 7 feet. The total weight of this machine is about 22 cwts., and it is arranged to cut from 2½ to 3½ feet under the coal. It is fitted with a motor that takes 25 amperes at 400 volts. Allowing for the loss on conversion of electrical into mechanical energy, this represents about 10 H.P. as the normal load for the machine.

The medium size has a total height, including that of the rails, of 17½ inches, with a width of 2 feet 8 inches, and a length over all of 9 feet 6 inches. Its weight is about 30 cwts., and the depth of cut taken is from 3 feet to 4½ feet. The motor takes 35 amperes at 400 volts, which, after allowing for efficiency, leaves about 16 B.H.P.

The large size has a total height of 22 inches, including the rail, with the same width and length as the medium size, while the depth of cut may be from 4 feet to 6 feet. Its weight is 2½ tons, and the driving motor takes 55 amperes at 400 volts, which, after making due allowance for efficiency, leaves about 25 B.H.P. available.

Although of different sizes the design of these machines is the same in each case, and all are fitted in such a manner that various lengths of cutting bars can be used, as the bar fits into a socket, which, with the gearing, is carried upon a table which is movable, and allows of the bar being swung in and out of the holing, or tilted up and down while working to whatever angle

may be required. The machine will thus cut from either side, and can be made to open its own way into the coal. While at work the bar can be raised or lowered if necessary, and the thread upon the bar acting as a worm conveyer helps to clear the cuttings out from the holing. In addition to the rotary motion a reciprocating motion is also given to the bar. The travel of the machine is arranged in the usual way, a small drum being provided which is worked by means of a pawl and ratchet wheel, the rope from the drum being carried forward and passed round a wheel which is fastened to a firmly-set prop; after passing round the wheel the rope is brought back and the other end fastened to the cutter-bar bracket. A connecting-rod is attached to the pawl, and works in a slotted disc, which is driven from the motor; by varying the distance of the movable connecting-rod pin from the centre of the slot the feed can be adjusted to suit the requirements. A guide gear, worked by a screw, is arranged in front of the drum, so as to lead on the haulage rope evenly from side to side. The gearing is entirely enclosed, and runs in an oil bath. The motor, which is a series wound multipolar, is also enclosed and protected from damage by falls, and fitted with carbon brushes, so as to reduce sparking to a minimum.

The machines are made so as to cut their own floor where necessary, or can be arranged to cut at any required height above the pavement level.

A machine, suitable for cutting at the bottom of the seam, is shown in Fig. 105, and is known as the **Undertype Cutter**; while one fitted for cutting above the floor level is shown in Fig. 106, and is usually called the **Overtype**.

A considerable number of machines of the above types are now at work, and are giving very satisfactory results, especially where the cutting is done in the bottom of the coal seam itself.

The Disc Type of Machine.—This class of machine, which is well adapted for longwall work, consists of a wheel, varying from 3½ feet to 6 feet in diameter, projecting from the frame of the machine, and supported by a suitable bracket. The wheel is driven by suitable mechanism, and is furnished with tool steel-cutters, fixed in suitable boxes placed at intervals round the periphery; feed gear for dragging the machine forward is also fitted. During the forward motion the cutter wheel revolves, cutting under the coal like a horizontal circular saw. A well-known machine of the disc type is that of Clarke & Steavenson, whose firm was among the first to apply electricity to the driving of coal-cutters. The machine is built of steel throughout, and is well designed, and of exceptional strength.

Fig. 105.—Hurd Coal-cutter (Undertype).

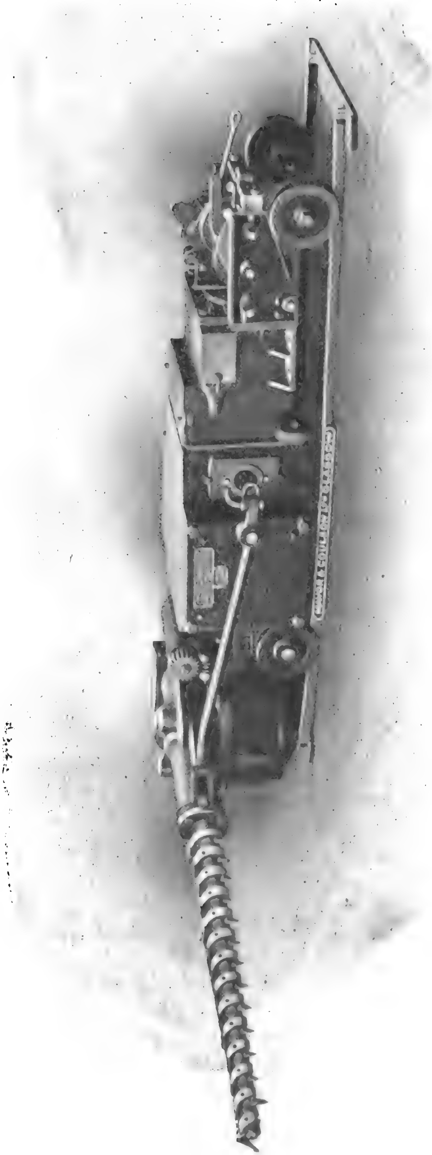

Fig. 106.—Hurd Coal-cutter (Overtype).

The design is the outcome of many years experience of the working of coal-cutters, and alterations have been introduced from time to time in order to enable it to fulfil the somewhat exacting conditions required for successful coal cutting. At the present time its mechanical parts are almost perfect, and the machine is one that will work with credit under the most unfavourable conditions. It was first introduced at the Lidgett Colliery in 1893, and the success was so marked that the machine has since been adopted in many collieries in both Scotland and England, while some have been exported to our colonies, altogether over 130 of these machines being now at work. At Lidgett the company has a compressed air plant and an electric plant working side by side, and are thus in a favourable position to make comparisons; and they state that they strongly recommend electricity, as "the first cost of plant is cheaper, the efficiency greater, and the cost of maintenance much less."

The machine is made in two types, known as the **Standard** and the **Low** type.

The *Standard*, of which Fig. 107 will give a general idea,

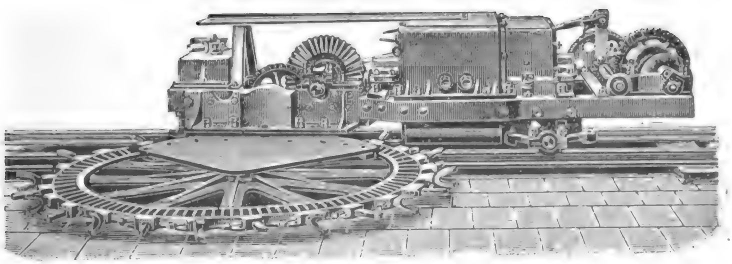

Fig. 107.—Clarke & Steavenson's High-type Coal-cutter.

stands 26 inches above the rails, and is fitted with a 5-foot wheel. Its total length is 8 feet 6 inches, while its width is 3 feet, and it weighs about 2 tons 5 cwts. The motor which drives the machine is of the enclosed type, and all windings, brush gear, connections, &c., are protected from injury by being enclosed in a strong iron casing which is thoroughly gas tight. This casing is shown in Fig. 108.

The motor has a normal working load of from 23 to 25 H.P. and is capable of giving over 40 H.P. without risk for short periods, it will thus be seen that under normal working load the motor will run practically sparkless, and without heating to any appreciable extent. For starting and stopping, a double-

pole, double-break resistance switch heavily built and fitted in a gas-tight case, is provided.

The *Low* type machine, which has been specially designed for use in some of the thin Scotch seams, is 19 inches in height, 9 feet long, and 3 feet wide. The cutter wheel is 4 feet in diameter, and works below the level of the rail, the machine thus cutting its own floor. This type of machine is shown in Fig. 109,

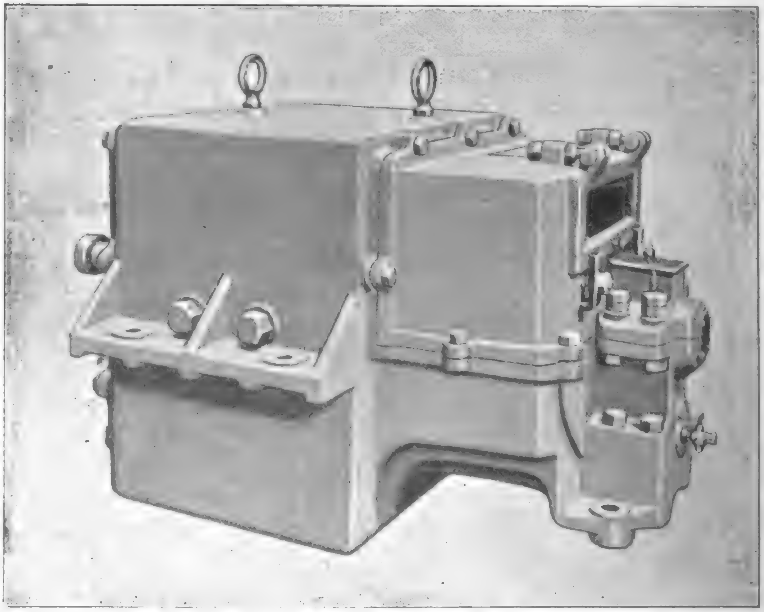

Fig. 108.—Coal-cutter Motor.

and comparison with Fig. 108 will show that the chief difference consists in the lowering of all parts as far as possible, in order to make the machine capable of cutting in very thin seams. The weight of the machine is also somewhat reduced, being in this type about 2 tons. Since starting this class of machine, the makers have been able, by making a very slight structural alteration, to fit it with a motor of 30 effective H.P. instead of one of 23, which was originally used, and this has been effected without increasing its height. This alteration will be of the greatest importance in cases where the machine is

cutting in a hard pavement, as cutting is only a question of power, no matter what the nature of the material. For hard, continuous work this machine is one of the best, the author having seen it running continuously overloaded to the extent of 50 per cent., and on some occasions, such as the jamming of the cutter-wheel, giving 70 H.P. for a minute or thereabouts. The arrangement of the motor and starting gear is the same as in the Standard type; but an advantage might be gained by altering the switch handles from the top to some place upon the end of the switch-box, as when working in very low seams they are sometimes inconveniently near the roof. In seams where naked

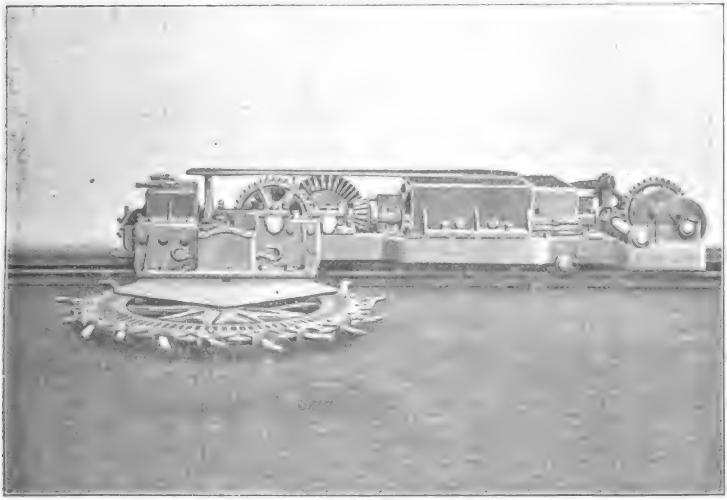

Fig. 109.—Clarke & Steavenson's Low type Coal-cutter.

lights were in use, the motor casing might also, with advantage, have one or two small holes, closed with wire gauze of fairly open mesh, made in it. This, while preventing anything large enough to do damage from entering, would allow air to circulate, and would thus keep down heating, even with the machine running constantly overloaded.

The cutting speed of the periphery of the disc is about 300 feet per minute. Twenty cutters are used, half of them being single and the other half forked, as shown in Figs. 110 and 111.

The spread of the fork is about 4½ inches, so that the groove

which they cut in the coal or underclay is about that width, or slightly over. For thin seams, where cutting must be done in the floor under the coal, these machines give excellent results, the actual amount of cutting depending on the conditions and the handling of the machine. The author has seen the *Low* type machine cut 42 yards of face to a depth of 3 feet 6 inches in $1\frac{1}{2}$* hours, without a single stop, this being in a fairly hard fireclay. Several of these machines have lately been set to work in the thin seams of Lanarkshire, and, judging from the results obtained, there is likely to be a considerable extension of their use at an early period.

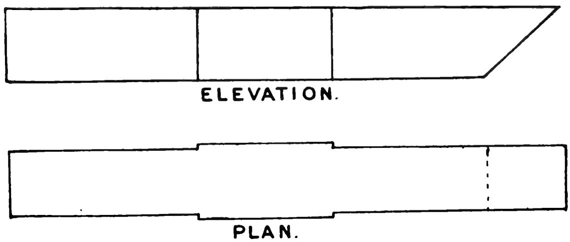

Fig. 110.—Single Cutter for Clarke & Steavenson's Machine.

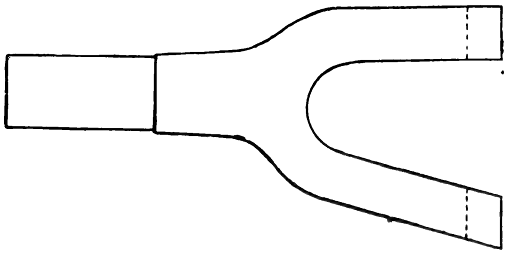

Fig. 111.—Double Cutter.

Until lately this machine was employed for cutting continuously in the one direction. As cutting back and forward is often a necessity in the Scotch seams, the machines that have lately been introduced into some of the Lanarkshire seams have been fitted with a roller at the bottom of the machines, and bridles for either end, to allow the cut to be made either backward or forward. Although the cutting wheel is practically at the back end of the machine, when working in its proper direc-

* Since writing the above the same machine has cut 48 yards in 53 minutes to a depth of 3 feet 6 inches.

tion, this causes little or no trouble when the machine is made to travel backwards. The attendant, being in front of the machine instead of behind, has to be a little more careful, and the shovelling away of the material from the cutter wheel is a trifle more awkward, otherwise the machine works as well as when going forward. In cutting back, the cutters have to be changed, so as to slope in the opposite direction to that required when cutting forward, the motor being reversed by simply reversing the brushes.

Another machine of the Disc type that is doing good work is that made by the Diamond Coal Cutter Company, Normanton. Like most other successful machines, it has been improved considerably since first set to work, the improvements being the result of actual experience gained from the working of the machine.

The machine (Fig. 112), when driven electrically, is fitted with

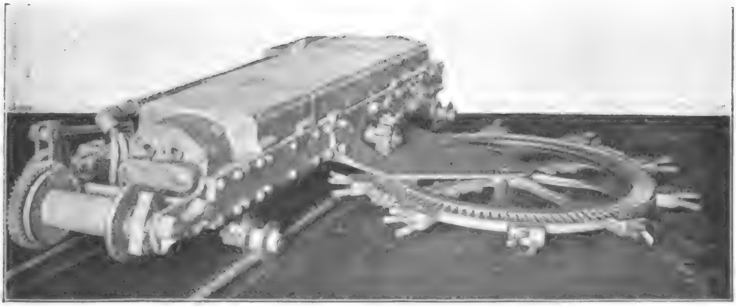

Fig. 112.—Diamond Coal-cutting Machine.

two motors, one at either end. The armature shafts of the motors are connected to a disc in the body of the machine, the gearing to drive the cutter-wheel being taken from this disc. In some of the machines two three-phase motors are used instead of continuous current, the gearing being the same. The cutter-wheel is made in two halves, and bolted together; this admits of easy transport should it be necessary.

The cutting tools are all single, and are fixed in a staghead cutter-box (Fig. 113). This box is bolted on to the rim of the wheel, the tools being put in from the inside, and kept in place by a flange and the projection upon the wheel to which the box is secured. The spread of the tools is obtained by their arrangement in the tool-holding box. It is claimed for this arrangement

that increased rigidity, regularity of cutting, immunity from breaking off in the sockets, and easy means of changing are obtained. The machines are fitted with two 10 to 15 B.H.P. motors, completely enclosed in gas-tight cases, and also with combined starting and reversing switches.

A number of machines of this class are at work in some of the thicker Yorkshire seams, and are there undercutting the coal to a depth of 6 feet 6 inches. There is not the slightest doubt that, where circumstances admit, deep cutting is most desirable, as not only does it save labour in moving the machine itself, but it concentrates the workings, and reduces or completely does

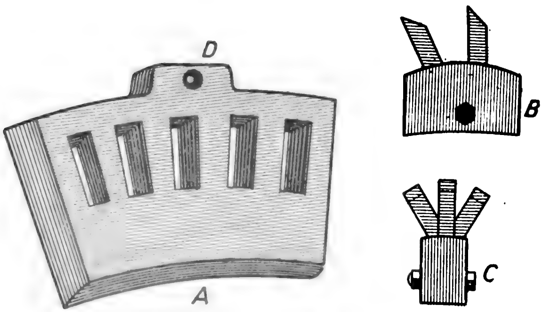

Fig. 113.—Diamond Cutter-box.

A = Part of rim of wheel. | C = Front elevation of cutter-box.
B = Elevation of cutter-box. | D = Attachment for cutter-box.

away with the necessity for shot-firing, thus improving the safety of the mine (Fig. 114).

The machines are also working in many thin seams cutting their own floor, the depth of cut in such cases being the usual 3 feet 6 inches or thereabouts. The actual rate of cutting varies with conditions, as in all the other cases already mentioned. There is one case recorded where this machine has cut 83 yards per eight hours' shift to a depth of 5 feet 6 inches under, the distance named being the average rate during two years working. The seam was 4 feet thick and flat; the holing was done in a dirty bottom coal; previous to the introduction of these machines the output was 3 tons 5 cwts. per man, which was increased by the machines to 6 tons per man. Shot-firing was also reduced from 35 to 40 shots per day to one occasionally, owing to the increased depth of holing. The Diamond Company have lately brought out an arrangement for adapting the machine to cut its own way into the coal. The apparatus is placed under the rails

upon which the machine rests, and the machine moved into the face by a screw, the cutter-wheel being kept revolving, thus cutting its way in. The haulage gear is thrown out of operation until a sufficient depth has been attained.

One great advantage is that most of the working parts of the Diamond machines are interchangeable, and where a number of machines are at work it is only necessary to keep one set of spare parts, as these parts will fit any of the machines. The machines can be made to cut in either direction without trouble, and are fitted with a reversing switch to effect this. As already stated, polyphase motors have been fitted to some of the machines; where such has been done the use of slip rings for starting have been entirely dispensed with, the starting torque being got by letting the motor make a few revolutions before taking up load.

Fig. 114.—Fall of Machine-cut Coal; depth of undercut, 6 feet.

This is done by means of the disc already mentioned, from which a projecting pin drives the gear, the arrangement allowing the motor to make about six revolutions before this pin catches. The chain type of coal-cutter is used chiefly in "stoop and room," or "pillar and stall" workings, but so far has not been adopted to any extent in this country.

In America, however, this class of machine is much used, and with good results, so that its adoption over here can only be a question of time, because if American owners can work "stoop and room" advantageously by machinery, there is no good reason to prevent the same thing being done by others. The question of wages and the scarcity of labour may, to some extent,

favour America in regard to this, but against that is the fact that most of the British coals are more difficult to under-cut than American (as instanced by the power provided for American

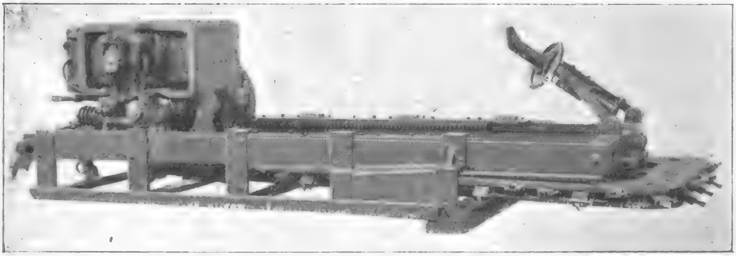

Fig. 115.—Jeffrey Chain Coal-cutter.

coal-cutting machines as compared with British), which renders them the more likely to produce good results if under-cut mechanically.

The best known machine of the chain type is that made by the Jeffrey Manufacturing Company, and largely used in American mines. This machine is shown in Fig. 115. It is 29 inches in height over all, and is built to cut 5 feet 6 inches in depth and 39 inches width, or 7 feet in depth with a width of 44 inches, the height of the cut being about 4 inches. There are three principal parts, the bed frame, the sliding-chain frame, and the motor carriage; a feed rack and cross-bar, on which rests a screw jack for taking up the back thrust, is fitted upon the frame.

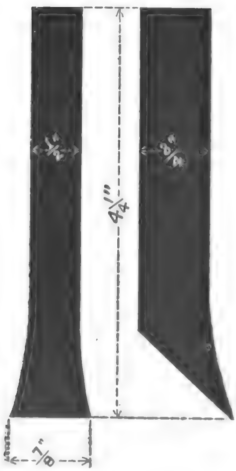

Fig. 116.—Jeffrey Cutters.

The cutter frame is triangular in shape, the sprocket wheel forming an apex, while two small wheels are fixed in the cutter head for guiding the cutting chain, these forming the base. The driving and feeding mechanism is mounted on the carriage. The cutters, of which Fig. 116 is an illustration, are nearly straight, with a slight hook at the cutting end, and must be carefully set and kept in good condition.

When working the chain is driven round, while at the same time the cutter head and frame are carried forward into the coal. After the cut has been completed the machine has its travel reversed, and the cutter frame is drawn in, the machine is then slid along a distance equal to the width of the cut, and operations recommenced. In order to fix the machine firmly in position two jacks are used, the front one being screwed up to the face of the coal and the rear one to the roof. The machine is worked by two men—the operator and an assistant—who sets the front jack, and shovels back the small coal from the cutters.

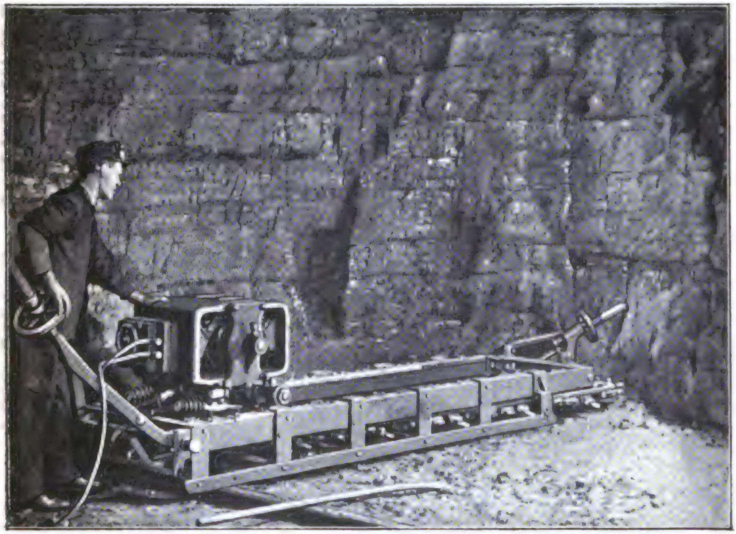

Fig. 117.—Jeffrey Chain Machine at Work.

When the cut is completed, the machine is moved by means of crowbars across the skid boards laid down for this purpose, and although the weight of the machine is over 2 tons, it is easily moved by two men. The operation of cutting by means of this machine is shown in Fig. 117.

When under-cutting stoop and room workings by machinery the machine has to be shifted from place to place at frequent intervals. To accomplish this with as little loss of time as possible a special truck (Fig. 118) is provided. This truck is fitted with a sliding bottom that is run out underneath the

frame of the machine, which is then made fast, the whole being dragged back on the truck by the aid of the winch fixed at the end. Here, again, the two men in charge of the machine do all that is required. After loading upon the truck, which has the same wheel gauge as that of the colliery tub, the machine is

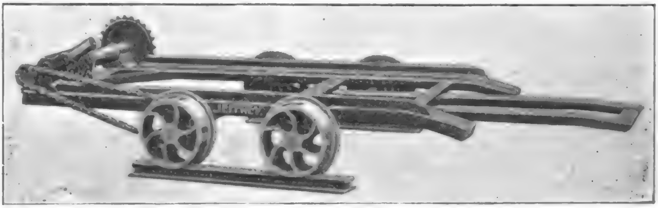

Fig. 118.—Jeffrey Angle-iron Truck with Self-propelling Gear.

conveyed along the tram road to the next working face. The rear end of the truck is then lifted, and the machine slides off, reaching at once its proper position to begin working.

To prevent the necessity of wiring each room, a means of transmitting the power from the feed-wire in the road is

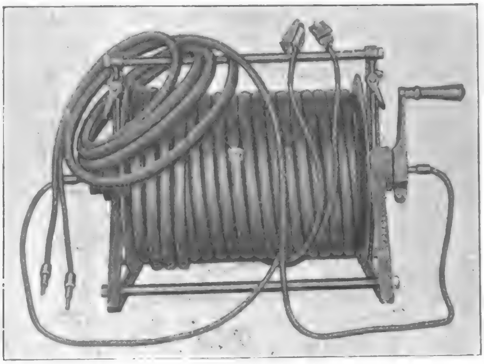

Fig. 119.—Reel and Cable for Coal-cutter.

provided. It consists of a cable, which is moved about the mine with the machine. This cable is usually about 250 feet long, and is wound upon a reel. It is of the twin type, both cables being placed side by side, thoroughly insulated from each

other, and then bound together. On the ends of each are hooks for making contact with the main cable. After this contact is made the reel is carried into the room along with the machine, the required length being wound off, the other ends are fixed to the motor terminals, and the machine is in a position to start work. The reel, with cable wound on, is shown in Fig. 119.

The dimensions of the ordinary machine are:—Length, 10 feet 3 inches; width, 3 feet 8 inches across the chain and cutter-bits; and height, about 29 inches. As already stated, the total weight is about 2 tons 13 cwts., while the weight of the truck is about 5 cwts.

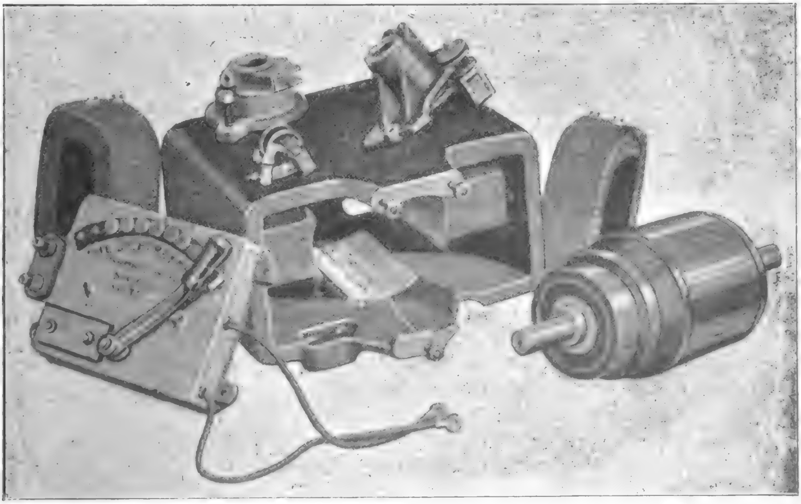

Fig. 120.—Parts of Jeffrey Coal-cutter Motor.

The motor, which is shunt-wound and gives about 15 H.P., is of the multipolar type, with two field coils, the frame being so arranged that the windings are protected from injury, although the motors run open. The armature is of the ironclad type, which provides protection for the winding.

All the parts of the motor, together with the starting switch and resistance box, are shown in Fig. 120.

The Jeffrey Company give the following as their record performance, which was accomplished with a machine built to undercut six feet with a width of forty-four inches:—Number of cuts 6 feet deep, 104; time taken, 9 hours and 40 minutes;

lineal feet of face cut, 333. The truck used was of the self-propelling type, and the machine was moved six times, the cutting being accomplished in five rooms and six narrow places. While this is a remarkable performance, there is probably little chance of doing anything like it in Britain, for two reasons. First, British coals are, on the whole, harder and more difficult to cut than the average American coals; and secondly, the machine would be worked by persons who had been accustomed to it for a considerable time. This consideration could, of course, be realised, and, indeed, it is surprising to see how much the amount of work done by any coal-cutting machine will depend on the ability and willingness of the workmen in charge. The working of these machines is quite simple, but, like all other classes of machinery, they have little tricks which vary in different seams, and are due to different conditions. These should be carefully watched, and, once noticed, precautions should be taken for their future prevention. Attention to the front and rear screw-jacks is of the utmost importance; they should be set tight, and followed up after cutting has commenced.

In thick seams worked by the stoop and room system, it is often advisable to shear one side of the coal after it is undercut. When this is done the coal is obtained with the minimum of blasting and breakage. The Jeffrey Company make a machine for this purpose, which closely resembles their heading machine. It consists, like the latter, of three parts—the bed frame, the chain cutter frame, and the motor carriage. The bed frame is constructed with two rectangular steel channel bars and two steel angle bars firmly braced together. A steel casting joins those two channel bars at the front end of the frame, and forms a guide for the cutter frame. Just behind this casting are rivetted two lugs which support the split clamp for the front jack. The main jacks are fixed between the centre and the back end of the bed frame. On each side of the supports for the main jack bearings for truck wheels are fixed. The cutter consists of one steel centre rail, a cutter head, and two steel guides, in which the chain runs. The motor is of the four-pole type, with two field coils, and is so constructed as to have complete protection for all parts from any falls of material that may occur. The machine, which is shown in Figs. 121 and 122, weighs about 3000 lbs.

When about to be used, the machine is placed on the floor close to the coal, and the jacks are set in their proper position. The machine is then raised to the top of the seam and cutting commenced. After the first cut has been completed the machine

is lowered a distance equal to the depth of the cut, and shearing again commenced. The amount of work the machine will perform depends greatly on the nature of the coal; but from 50 to

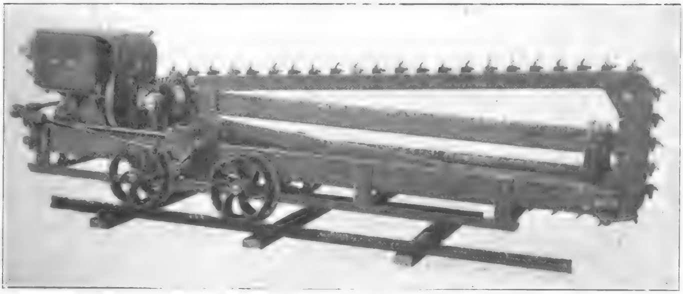

Fig. 121.—Jeffrey Shearing Machine.

100 feet of shearing in a seam 7 feet high may be taken as about the average. A single cut is 36 inches high, 4 inches wide, and 6 or 7 feet deep, as may be required.

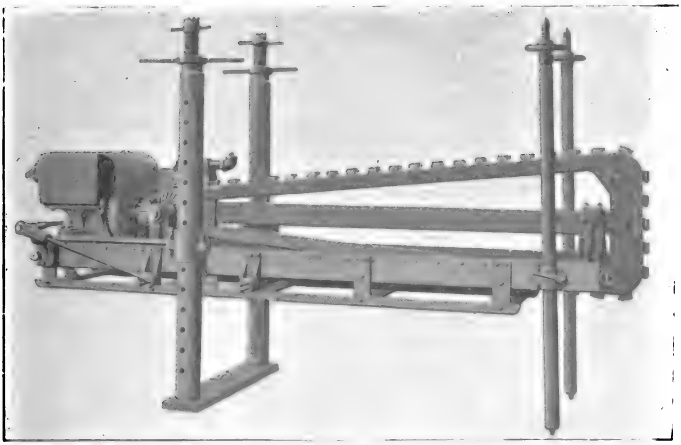

Fig. 122.—Jeffrey Shearing Machine ready to begin Cut.

The Jeffrey Company also make a disc machine suitable for use in long wall workings, a few of which are at work in this

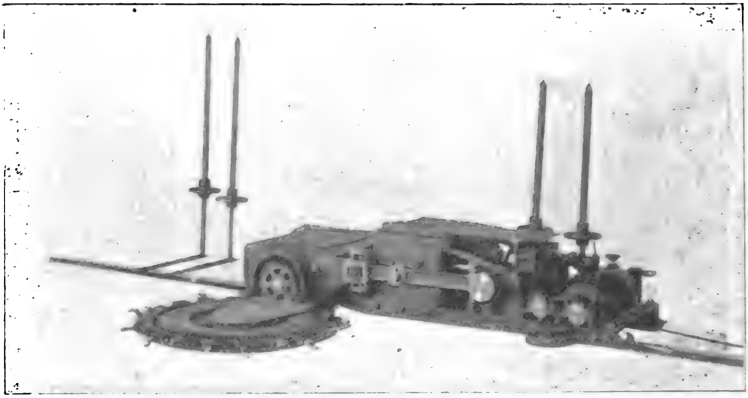

Fig. 123.—Jeffrey Long Wall Coal-cutter.

Fig. 124.—Jeffrey Long Wall Machine at Work.

country. The machine has some novel features, when compared with any of the disc types already described. It runs upon one rail only, the rail being kept in position by means of screw-jacks; it is claimed that this overcomes the tendency that exists in two rail machines to leave the rails. The cutter-wheel is lowered so that the machine cuts its own floor, as in the other cases already noted. An arrangement is fitted for tilting the cutter-wheel, so that small obstructions may be holed over. The machine is arranged to cut either backward or forward, but when running in its right direction the machineman is in front of the machine. The feed consists of the ordinary ratchet and pawl arrangement upon the haulage drum, and is driven by means of an eccentric. Three speeds are provided—8 inches, 16 inches, and 25 inches

Fig. 125.—Jeffrey Long Wall Machine at Work.

per minute. The feed can be stopped, started, or changed without stopping the motor. The haulage drum is fitted with a friction clutch, which slips, should the strain upon the haulage rope become too great. The machine is 8 feet 2 inches long, 3 feet 9 inches wide, and 19 inches high; its weight being about 32 cwts. or so. It is fitted with a motor of 25 B.H.P., which is completely enclosed. The machine, which is really a very ingenious one, is shown in Fig. 123, while Figs. 124 and 125 show the machine at work. The machine holes to a depth of 3 feet 6 inches, with a width of about 5 inches, under ordinary circumstances; but can be fitted with a larger cutting disc to hole deeper if required. The deeper cut requires a greater

expenditure of power on the part of the motor, and it is only where the seam is comparatively easy to cut that deep cutting can be attempted with success.

The motors used to drive coal-cutters are, for the most part, series wound, especially if the machine is of the disc type, the chief advantage gained by using this form of winding being the increased starting power as compared with any other class of winding, a very important matter in many instances. There is, however, the drawback that this motor will take power in proportion to the work it has to perform, and should the machine be made to jam itself in such a way that an enormous amount of work might be required from the motor to extricate it, the motor will take current until the fuse blows or the armature gets burned out. The motors are generally multipolar, having four poles and only two field coils. Fig. 126 will give a general

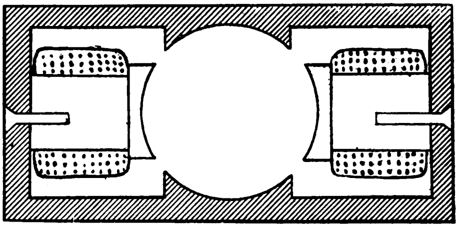

Fig. 126.—Section of Coal-cutter Motor.

idea of the section of such a motor, the object of making it, as shown, being to keep down the height to the smallest possible amount, and at the same time allow the armature to be of as large a diameter as possible under the circumstances.

The armature may be either wave or lap wound. If the former, two sets of brushes set at 90 degrees and with twice the ordinary section may be adopted. If the latter, four brushes, or two sets in parallel, may be used. The chief point in connection with the motor is the rigidity of the armature, as the amount of vibration tells very greatly upon it unless its construction is of the most rigid description, the common failure in many armatures being the wrenching away of the coils from the commutator lugs. This may be avoided by using a commutator with solid lugs and the ordinary mica insulation between, or, in the case of a machine already at work, the ordinary type of commutator lugs may be strengthened by lacing them together with whip cord, and then putting a band of binding wire upon mica insulation, on the top of the coils

where they join up.* The work done by such an armature is of so variable a nature because of the continually changing load, that it is absolutely necessary to have the coils very firmly bound into position, and for this purpose the best piano wire should be used, the bindings being firmly soldered together and bound at frequent intervals, and, of course, well insulated from the armature coils.

Care should be taken to keep the lugs of the commutator as short as possible, as if too long there is a tendency for an arc to be formed between them and the motor casing. The brush gear should also be kept as far from the casing as possible, and should be of such design that the brushes do not easily jump from the commutator during periods of excessive vibration. Unless this point is attended to, an arc may similarly be started between them and the motor casing. It must be remembered, in connection with the above, that the motor of a coal cutter is, in all cases, one in which all parts have to be packed into the least possible space, and at the same time the machine cannot be made to work under conditions such as exist in any ordinary case, but that vibration must always be reckoned on. It will thus be seen that great necessity for care and forethought exists in the design of a coal-cutter motor, especially as regards the armature. Failures, when they occur, are due, as a rule, to some of the causes already dealt with in Chapter III., and should be met with as there recommended. A good plan is to have the failures repaired on the ground, as it saves time and expense of transit. In most cases this can readily be done if the failure is electrical, if mechanical it can only be dealt with if the necessary machine tools are on the ground. The repairs will, at first, best be done by or under the supervision of a skilled electrical engineer, but many of the minor repairs may ultimately be left to some of the colliery mechanics, who should do all in their power to increase their experience in connection with the carrying out of such repairs.

Where coal cutting by machinery is in contemplation the colliery manager should consult some firm of electrical engineers who have had experience in such work, and get them to examine and report upon the suitability, or otherwise, of the seam for that purpose. Most firms who specialise in that class of work have mining men of experience associated with them, and are

* Since writing the above, the author's firm have adopted flexible connections between the conductors and the commutator, for the purpose of coping with the above difficulty, and although it is yet too early to say that this completely removes the source of trouble, it has certainly done a great deal to minimise such failures.

thus in a position to give sound advice. Once the plant has been laid down its starting and working should be left in the hands of the contractor for a week or two, but the colliery company should have the men they propose putting in charge of the plant on the spot, so that they may be instructed in the details of its working. If machinemen with previous experience can be got so much the better; but it is of little consequence whether that experience has been gained with electrical-driven machines or not, as any intelligent miner who will take a real interest in the work can be readily trained.

In starting the machine it is important to note that it may have become damp, and if so, there is a tendency to short circuit. This can be remedied by keeping down the voltage and letting the amperes rise; this heats the armature and expels the moisture. Another feature that sometimes presents itself is the starting of a machine near the pitbottom where the fall of voltage may be very small. Allowance will, in all probability, have been made for a considerable fall in volts, but until the workings are extended to some distance, the engine driving the generator must be run below its proper speed, in order to keep down the voltage. This may necessitate alterations of the governor so as to obtain the best results.

In conveying current to the working face the mains are led up the gate roads at about 80 to 100 yards apart, and a gate switch and connections fixed. These should be enclosed and gas-tight if the mine is a fiery one. The trailing cables are connected to a gate-end switch and to the coal-cutter which drags the cables along the face as it moves forward.

A cable connector has been brought out recently by Messrs. Davis, of Derby, which is suitable for such a purpose. It is so arranged that a live joint cannot be made even with the current on until the sheathing of the casing has closed the chamber. Fig. 126*a* shows how the joint is made. The trailing cables are secured to the connector by cone nipples shown at *d d*, and the two portions secured by a bayonet joint at *a b*. Two pairs of connections are required, and sparking from the live ends is rendered impossible by having the tongue *c* buried beneath the case.

Various opinions exist as to the best form of cable to use. The ordinary insulated cables used for mains do very well, and if care be taken to keep them clear of falling coal, rails, &c., will last a long time. Any sign of broken insulation should be attended to, and remedied at once. When the insulation, as a whole, begins to get defective, the cable may be removed and used for extending the mains, after being wrapped with tarred

cloth and given a good coating of tar, new trailing cables being substituted where required.

The cutters are another important consideration, and should be carefully sharpened and set, the proper spread being given. Once the best set, which will vary with the nature of the material cut, has been obtained, a template should be made and the cutters set to that template. The cutters should have sufficient clearance to enable the wheel to work freely without jamming, but too much should be avoided, as this has a tendency to make the cutter-wheel go down into the floor, or rise into the coal. When cutting has to be done in the coal itself it may become necessary to sharpen the cutter with a point, like that put on a miner's pick, as some coals cut much better when the

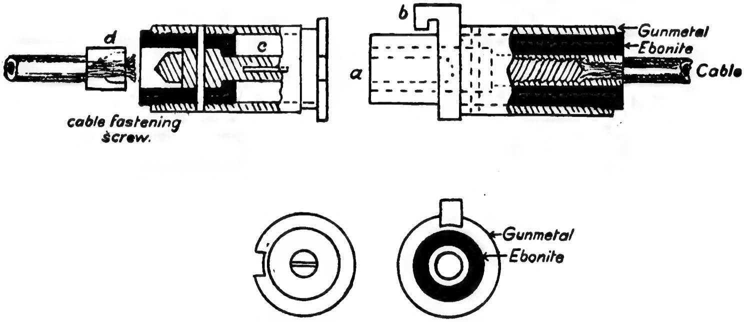

Fig. 126*a*.—Trailing Cable Connector.

cutting tool is so sharpened. A great deal depends on the nature of the coal, some coals cutting fairly well with the flat or chisel-faced tool, others requiring the diamond point already mentioned. The power taken by the machine while cutting, and the conditions of running, often show the necessity for alteration of the cutters. Where there is any tendency for the coal to fall on under-cutting, it should be well spragged close behind the machine.

The road upon which the machine travels should be well laid, and packed up level, so as to give the machine every chance. It is much better to expend extra work in securing the road than to have the machine to lift on to the rails once it has left them, a task by no means easy in a low working.

Cutting under a bad roof is one of the greatest drawbacks to machine mining, and all the skill and foresight of those in charge of the machine are required under such circumstances. The roof may be strapped by straps of wood, if the height of the

seam allows of this being done, or of iron, if the seam is very thin, this method being shown in Fig. 127. The straps should be removed after the machine had passed, props having previously been set to support the roof, and admit of their safe removal.

In working coal-cutters a great many minor details crop up which require attention, these are best dealt with by the person in charge; but one point must be emphasised, and that is, that the manager of the colliery, where such plant is installed, must look personally into all matters, and see that the work is being carried out on right lines. If this be done, there are few cases where the adoption of coal-cutting machinery will not prove a decided advantage to both master and workmen, particularly

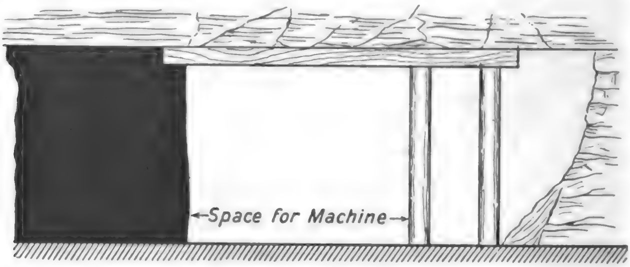

Fig. 127.—Strap to Bad Roof.

when the seams to be worked are thin, say, 3 feet 6 inches and under.

Cost of Cutting.—This matter is one that depends so largely on the various conditions of each particular case that little can be said with certainty about it. Another difficulty is the reluctance of those concerned to give information as to prices. The following are the results of a few cases that have come under the author's notice :—

	Seam 3 ft. thick.	Seam 2½ ft. thick.	Seam 20 inches thick.
	S. D.	S. D.	S. D.
Price per ton for filling coal, . .	1 0	1 2	1 9
Cost per ton for holing by machine,	0 4½	0 5½	0 10
Cost of power, &c., per ton cut, .	0 0·8	0 1	0 1·4

The above takes no account of interest and depreciation of capital, nor of repairs, all of which would have to be added. As

the above figures are from observations made over a comparatively small number of cases, they can hardly be taken as more than a rough approach to the average price that might have to be paid for seams of the thickness named. It may be further mentioned that the figures apply to cutting in hard under-clay, and that under such circumstances the percentage of small coal would be a minimum.

The actual saving in cost compared with hand labour varies from a few pence to as much as a shilling per ton, and in some cases even more.

The greatest saving is generally effected in the case of very thin seams, where working by hand can only be carried on at a profit during periods of high prices, and where the work must be discontinued, or carried on at a loss, when prices are low. The saving due to the use of machinery in such cases may make good what would otherwise be a loss, and enable the working of the seam to be continued during periods of bad prices. It will thus be seen that where the higher gain is shown it seldom represents that amount of actual profit, but only the possibility of working certain thin seams during the varying and unfavourable conditions of the market.

The following description of a coal-cutting plant, suitable for driving three coal-cutters, may be of interest. The plant in question has been laid down at the Over Dalserf Colliery, in Lanarkshire, and consists of a Tangyes horizontal engine, 20-inch cylinder, with 32-inch stroke, fitted with a high-speed governor, and running at 70 revolutions per minute. The flywheel is 14 feet 4 inches in diameter, with a turned face 20 inches wide, from which the generator is driven by means of a belt. The generator is of the multipolar type, with an output of 75 kilowatts, at a speed of 600 revolutions per minute. The field magnets are of specially permeable cast steel, joined in halves across the horizontal diameter, so as to provide ready access to, or removal of, the armature. Pole shoes are bolted to the poles.

The magnet coils are of high conductivity copper wire, insulated and wound on sheet iron formers, and detachable from the pole arms.

The armature core is built of special charcoal-iron annealed discs, insulated with varnish, and keyed to a cast-iron spider, detachable from the armature shaft. Air ducts are formed in the core to allow of ventilation, and the slots in the core are lined with insulated channels before winding.

The commutator is built of high conductivity copper bars insulated with mica, and mounted upon, and insulated with micanite from, a cast-steel sleeve secured to the armature hub.

The armature coils are of high conductivity copper, insulated and wound before being laid in the slots of the core on formers, and held in position by binders of steel wire insulated from the conductors by mica.

The brushes are of carbon, fitted with suitable adjusting gear mounted on a rocker bar.

The machine is fitted with three bearings which are lubricated automatically by means of oil rings.

The switchboard is made of two polished marble panels, divided by a marble partition, and framed with polished teak. The instruments mounted upon it consist of a double pole, quick break, lever switch, with carbon breaks, a dead-beat Stanley D'Arsonval voltmeter, to read to 500 volts, and a dead-beat Stanley D'Arsonval ammeter, to read to 250 amperes. Two safety single-pole fuses are also fitted, and are capable of rapid replacement, a spare one being kept for insertion should a fuse blow.

The cables leading from the switchboard to the pit bottom are $\frac{37}{14}$ size, and are suspended at intervals of 10 fathoms in the shaft. From the pit bottom cables of $\frac{19}{14}$ size are led to where the machine cable of $\frac{7}{14}$ size branches off.

Current is at present supplied to one Clark & Steavenson low type coal cutter, which undercuts the Virtuewell seam to a depth of 3 feet 6 inches. The cutting is done in the under-clay, the machine making its own floor. The height of the seam is about 2 feet 4 inches. More machines will be set to work as soon as sufficient ground has been opened for them. The present machine is cutting back and forward along a 95 yards face, and is doing good work.*

* Since writing the above the face has been extended to 200 yards; this length is cut to a depth of 3 feet 6 inches in about eight and a-half hours. A second machine has also been installed in another section, and is cutting 240 yards 3 feet 6 inches deep in a ten-hour shift.

CHAPTER IX.

MISCELLANEOUS APPLIANCES.

Miners' Lamps.—Ever since the introduction of the incandescent lamp, mining engineers and colliery managers have looked to its use as a safety-lamp in the working of fiery mines. That the incandescent lamp is absolutely safe in explosive gas is unquestionable, but other weighty considerations have prevented its extensive use in mines, except at pit bottoms and elsewhere, where it can be furnished with current from the mains. As a method of lighting the working face it is impracticable, and where electric lamps have to be used all over the colliery, they must, to a certain extent, approximate in form to the ordinary safety-lamps in common use

So far this question has only been partially solved, and many improvements will yet have to be carried out upon the already existing lamps before they are generally adopted.

The chief drawbacks to the use of portable electric miners' lamps are :—

1. Their weight.
2. Inability to stand rough handling.
3. Failure to indicate the presence of either inflammable or irrespirable gases.
4. First cost and upkeep greater than with oil lamps.
5. Action more or less uncertain.

The advantages of such a lamp, provided it be of good design and thoroughly reliable, would be—

1. Freedom from risk of an explosion due to breakage or wilful opening of the lamp.
2. Increased light, with every facility for making a thorough examination of the roof, which ought to considerably lessen the number of accidents due to falls.
3. The lamp is easily cleaned.
4. Such lamps are not extinguished if upset.

A portable electric miners' lamp is necessarily composed of two parts—the battery, which furnishes current, and the lamp itself.

The battery may be either primary or secondary—*i.e.*, the current may be supplied from a cell where it is produced by chemical action, or it may be derived from a dynamo by means of a

storage battery, which in turn gives it up to the lamp as required.

There are more difficulties in the way of primary batteries being used than exist in the case of secondary, and the only lamp that has really proved practically usable is one with a battery of the last-mentioned type.

With the primary battery the chief difficulties are that of having an arrangement which will produce the requisite energy enclosed in the necessarily small space at disposal, and kept within the limits of weight, and that of furnishing the supply of energy at a cost that will at all compare with that of existing oil lamps.

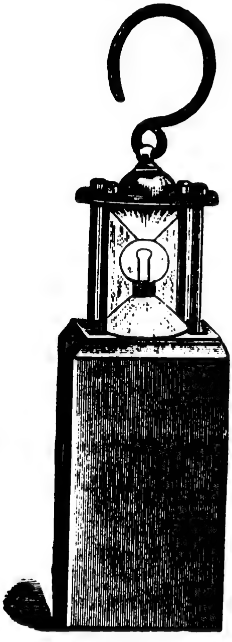

Fig. 128. — The Sussmann Electric Miners' Lamp.

With the secondary battery the difficulties are that of the delays incurred in recharging the battery, and uncertainty regarding its life, besides the difficulty of knowing whether the battery is fully charged or not before sending the lamps down to work.

At the present time the only electric lamp in use in this country, so far as the author is aware, is the Sussmann (Fig. 128).

This lamp is made in two forms: in one the lamp bulb is fixed, in the other it can be removed and replaced by another if necessary during the time the lamp is in use. In both types the lamp is carried in a cage which rests upon the top of the battery. A switch is provided, which lights or extinguishes the lamp at the will of the operator. The battery, which forms the bottom part of the lamp, is of the Faure type, and is made of two rectangular ebonite cells, each cell containing three elements. These elements, of which one is positive and two negative, consists of lead grids filled with paste, made by mixing oxide of lead with dilute sulphuric acid or sulphate of ammonia. The paste thus prepared, after being pressed into the spaces between the lead grids, is allowed to harden and become dry, after which the whole plate is placed in a bath of dilute sulphuric acid through which a current of electricity is passed. The effect of this current is to convert the oxide of lead into the peroxide,

and the metal into the spongy state. The plates, connected by strips of lead, are then placed in the cells, which are filled with the electrolyte. This electrolyte, which is of a gelatinous nature, highly porous and absorbent, is made a conductor by saturation with dilute sulphuric acid, and it is largely due to the use of this material that the lamp has been in a measure successful. The connection between the vulcanite top and the lamp and switch is made by flexible cords of fine wire, fitted with brass plugs which enter into holes in the lead plates.

The weight of the battery is about 3¼ lbs., and it gives an E.M.F. of about 2 volts per cell. The capacity is about 5½ ampere hours, which is sufficient to run the lamp used about ten hours when the cell has been fully charged.

In charging the batteries they may be put in circuit either singly or in series; probably by charging them singly there is less opportunity of the lamp only receiving a partial charge.

Recently a gas-indicating apparatus has been added to the Sussmann lamp; but how far this apparatus can be trusted for detecting gas has still to be shown; meantime it shows that the manufacturers are fully alive to what is required, and are doing what they can to make the lamp as perfect as possible.

Other portable electric miners' lamps have been brought out from time to time with varying degrees of success; but as none of them are being used to any appreciable extent, the author does not think that a description of any of them is necessary.

Lighting and Cleaning Lamps.—Another very useful application of the electric current is that of lighting ordinary safety-lamps. With the ordinary arrangements for lighting lamps, the screwing off and on of the bottom takes some time, hence lighting must be started a considerable time before the men begin to go down, and thus a considerable amount of illuminant is consumed by the lamps before they are taken into the mine at all.

If the lamps are fitted to light from an electric current, they can all be cleaned, locked, and prepared, the lighting being done at the last moment, and in a very short time. Some form of igniter must of course be fitted to the lamp. The one used at the Blanzy Collieries, and exhibited at the Paris Exhibition, is suitable for igniting lamps using either mineral or vegetable oil, and can be adapted to any of the usual forms of safety-lamps.

It consists of a ring made of two metal washers, separated by asbestos, inserted between the glass and the gauze. Each washer is fitted with an inside appendage which connects with a platinum wire. The upper washer is so fitted that it makes good metallic contact with the metal of the lamp, the lower being insulated from it. If connection be made to a suitable

source of current, it passes through the lamp, raising the platinum wire to a red heat, and kindles the wick communicating with the oil vessel. A suitable stand is provided for making the necessary contact, and lamps are lighted with little loss of time.

Small electric motors, totally enclosed, and fitted with a buff or polishing wheel on each end of the armature shaft, are also in use for the purpose of cleaning safety-lamps after they have been in use for the day. These little machines are very convenient, and no handier method of doing this work could be devised.

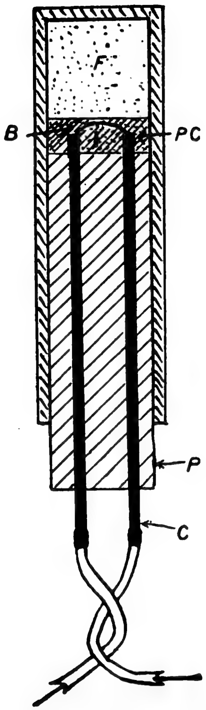

Fig. 129.—Section of Low-Tension Fuse.

F = Fulminate of mercury.
P C = Primary composition.
B = Platinum bridge.
C = Copper wires.
P = Plug holding wires.

Shot Firing.—For this purpose electrical methods have been in use for a considerable time, and with eminently satisfactory results.

The old methods of firing by ordinary safety fuses have several disadvantages, among them being risks of missfires with defective fuse, danger of ignition of gases if present, and the large amount of smoke given off, and consequent contamination of the atmosphere from burning fuse. Although the use of electric methods have not done away with all these drawbacks, the dangerous element has been eliminated. Greater safety, fewer missfires, and perfect safety in approaching the shot after one has occurred have been gained. In addition to this, there is neither flame nor smoke from fuse, and it becomes possible to fire any number of shots simultaneously.

Two methods of electric blasting are in use, the high-tension method and the low-tension method.

In the *high-tension* system the explosion is caused by a spark,

which is made to pass between two points inside the detonator. In the *low-tension* system the two wires are connected at their ends by a short piece of fine iridium platinum wire, which offers considerable resistance to the passage of current. This wire becomes heated to redness, and ignites the priming, which, in its turn, explodes the detonator. A section of a low-tension fuse is shown in Fig 129.

In the high-tension system the cost is very slightly under that of low-tension, but this is almost its sole recommendation, and it is gradually giving place to the low-tension system altogether. The chief advantages of the latter are that the fuses are less subject to deterioration, than high-tension fuses, and for that reason more suited for storage. They can also be readily tested by means of a galvanometer and battery in order to see whether they are alive, which cannot be done with a high-tension fuse. When such tests are made the fuse should be placed in an iron box, so that in the event of it being accidentally fired, no damage will be done.

The fuse is exploded, in most cases, by a small magneto-electro machine, the windings of which are varied to suit the class of fuse used. These machines are of different sizes and weights, one, capable of firing three shots in series, weighs about 7 lbs., while a larger one, which can deal with eight shots in series, weighs about 18 lbs. (see Fig. 130).

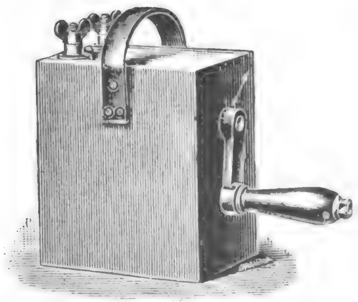

Fig. 130.—Magneto Exploder.

A useful auxiliary is a reel to carry the wires from the exploder to the shot hole. Such an arrangement is shown in Fig. 131. Both wires are separate on the reel and can be run off to any required length.

In connecting up the cables to the shots, either the series or parallel systems may be used; or modifications of both, to suit the circumstances, may be adopted.

In the series system one wire of the fuse is connected to the cable; the other connects the first hole with the second; the remaining wire from the second hole being connected to the

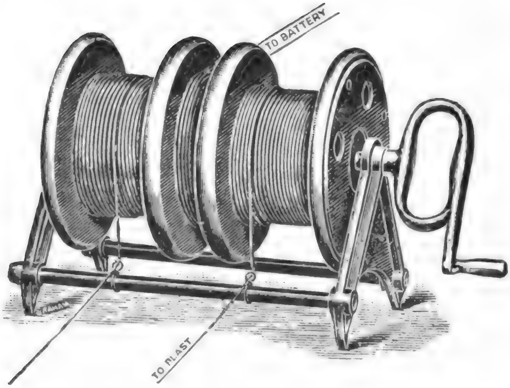

Fig. 131.—Wire Reel for Shot Firing.

third, and so on (Fig. 132). When all are connected the remaining wire of the last hole is joined up to the other cable.

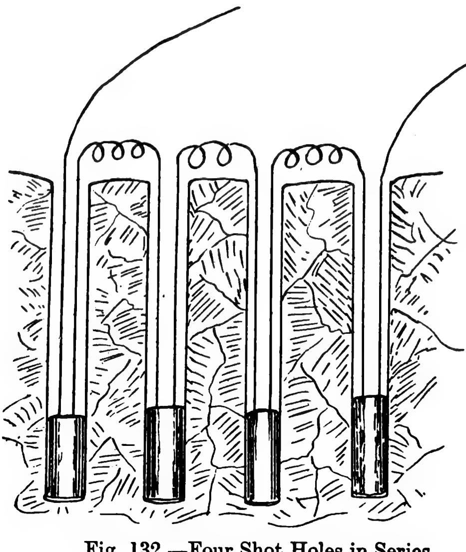

Fig. 132.—Four Shot Holes in Series.

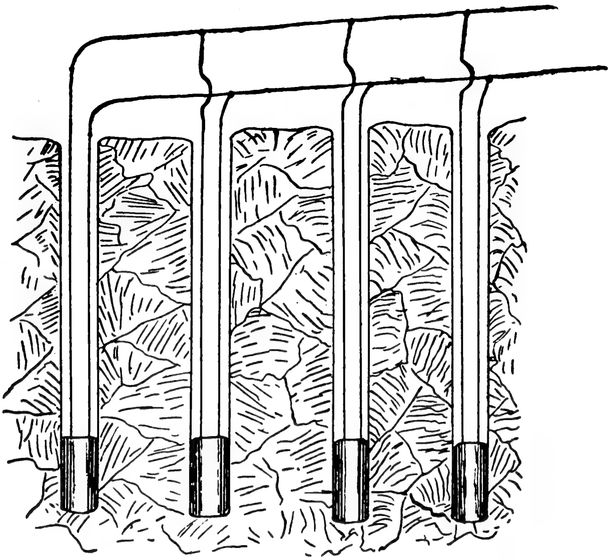

Fig. 133.—Four Shot Holes in Parallel.

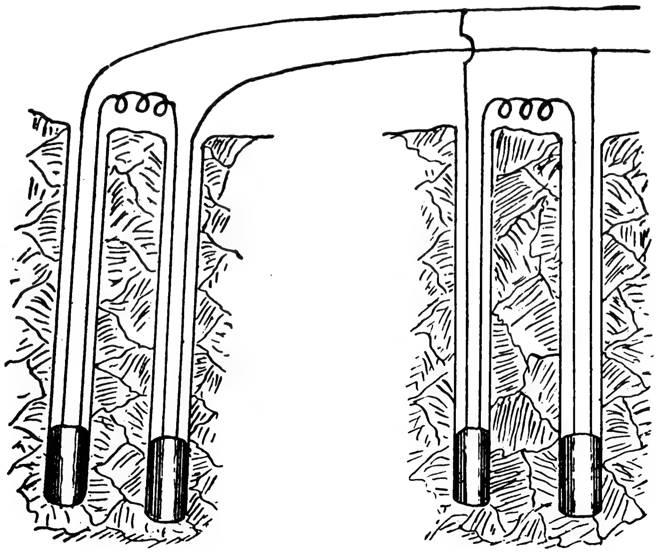

Fig. 134.—Four Shot Holes in Multiple Series.

In the parallel system (Fig. 133) one wire from each fuse is connected to one cable, and the other to the second cable.

A combination of both of the above methods, known as the multiple-series system, is shown in the diagram (Fig. 134).

Whatever form of connection be used, the following points ought to be observed :—The hole should be firmly and carefully tamped, afterwards the ends of the fuse wire should be untwisted and cleaned with a piece of sand or emery paper, and connected to the firing cable by twisting the two ends firmly together, taking care that lead and return are kept separate. The ends of the twin cable can now be fastened by placing a stone or piece of coal over them, and the cable run off the reel until a place of safety is reached. The ends of the cable are then connected to the terminals of the exploder, and the handle turned sharply. When full speed is attained the pressure of the button makes electrical contact and fires the shot.

In order to avoid missfires, it is best to use an exploder yielding more energy than is, theoretically, required, and detonators of sufficient strength. In very wet places it may be necessary to insulate the bare joints between the fuse and the cable with rubber tape.

The cable should never be connected to the exploder until everything is ready and everyone in a place of safety, and the button should not be pressed until a high speed has been obtained.

If the above precautions are observed, shot-firing can be carried out with ease and safety.

An idea prevailing in many quarters is, that the cost of electrical shot-firing is high as compared to the ordinary methods. This is not the case, however, as, if compared with methods that require igniters, it is lower; while comparison with methods in which fuse only is used, shows it to be only very slightly higher. The chief points in its favour, however, are its greater safety and certainty, and on these heads alone it would be worth a slight additional cost. It also admits of the simultaneous firing of a large number of shots, and this is of considerable importance, particularly in such work as shaft-sinking and driving of stone drifts, as better results are obtained by firing the shots collectively, and less time lost by the workmen in waiting for the smoke to clear.

Power Drills.—For certain classes of work machine drills are of great service, especially where many stone drifts have to be driven, although they are chiefly used for preparing holes for blasting down coal. Such drills may be divided into two classes, "Rotary" and "Percussive." For moderately-hard ground the

rotary type is very serviceable; but where boring has to be performed in really hard material, the percussive drill is the best.

The rotary drill is well adapted for driving by electricity, and is, indeed, frequently driven in this way. On the other hand, it is much harder to apply electricity to the successful driving of a percussive drill, and, consequently, this form is seldom found driven electrically.

The main requirements of a power drill are that it should perform its work well, should be easily and rapidly handled, and should combine lightness with strength. For use in places where

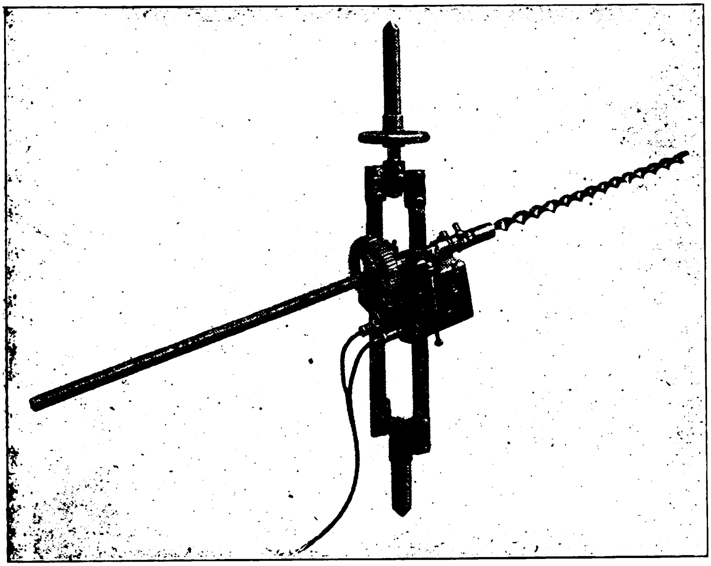

Fig. 135.—Jeffrey Electric Drill.

coal-cutting is being done by electricity as motive power, and where the coal may require blasting, the Jeffrey Manufacturing Company make a good drill of the rotary type. It consists of a standard capable of being set to any required position, and which can be jammed between the roof and floor by means of a strong screw. The driving motor is carried upon this standard, and rotates the boring bit by means of spur-wheel gear, the forward feed being obtained by the use of a screw.

The drill is shown in Fig. 135, and is arranged so that it can

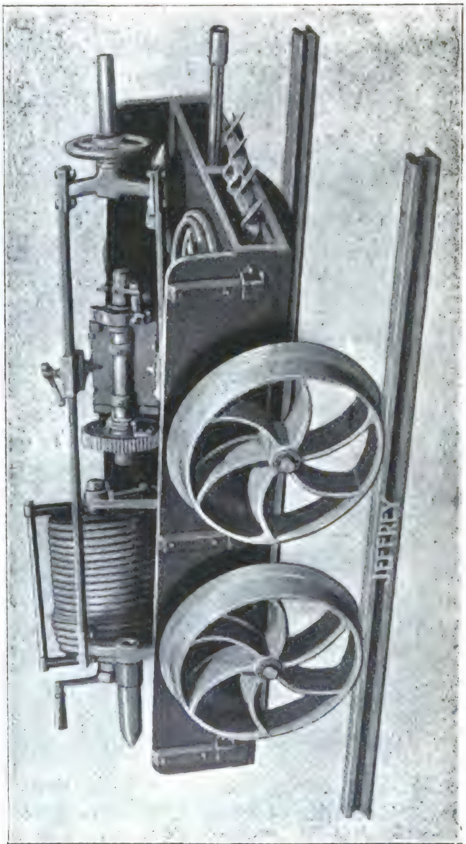

Fig. 136.—Jeffrey Electric Drill and Truck.

be turned either in a vertical or a horizontal plane, which admits of holes being bored at any angle. When these drills are used in conjunction with chain coal-cutting machines, it becomes necessary to remove them from place to place at frequent intervals. This is accomplished by loading them upon a truck specially constructed for the purpose (Fig. 136).

Another machine, designed for boring in rock, stone, and other coal-measures strata, and known as Grant's drill, has recently been set to work. This machine is of the rotary type, and consists of the following parts :—

The drilling machine proper.
The supporting column.
The shaft for transmitting power from motor to drill.
The motor.

These parts are shown in Figs. 136*a* and 136*b*.

In Fig. 136*a* the drill is fixed in position for boring a breast-hole, while in Fig. 136*b* the drill is arranged for boring at the bottom of the face. In the drill the whole of the parts, with the exception of the outer casing, is of special steel, and fitted with bronze bearings. One pair of machine-cut bevel-wheels are used, and power is transmitted through them from the motor by means of a telescopic shaft. The drill shaft is threaded throughout its entire length, and is furnished with a detachable chuck. The thrust-bearing is of the conical-roller type, and is designed for a working pressure of 6 tons. The feed-gear is controlled by means of a brake, and can be adjusted from $\frac{1}{10}$ of an inch per revolution to zero, the adjustment being made by screws fitted with wing nuts, one on either side of the casing. This allows of ready adjustment, even in cramped situations.

The length of travel without changing is 22 inches, and can readily be made more. The spindle is released from the feed-jaws by throwing out a link, and can thus be easily moved to and fro. The whole is enclosed in an oil-bath.

The column which carries the drill consists of a weldless steel tube $4\frac{1}{2}$ inches diameter, the thickness of metal used being $\frac{3}{8}$ of an inch. It is fitted at the foot with two screw-jacks, which work in bronze nuts. A short horizontal arm, capable of turning round or moving up and down, is carried by the column, and to this arm a slide block is fixed, to which the drill is secured. The combined motions thus furnished admit of holes being bored at any angle or height, and allows of easy changing of the drilling tools.

The telescopic shaft consists of a steel tube into which two solid shafts slide; each of these shafts are fitted with a universal

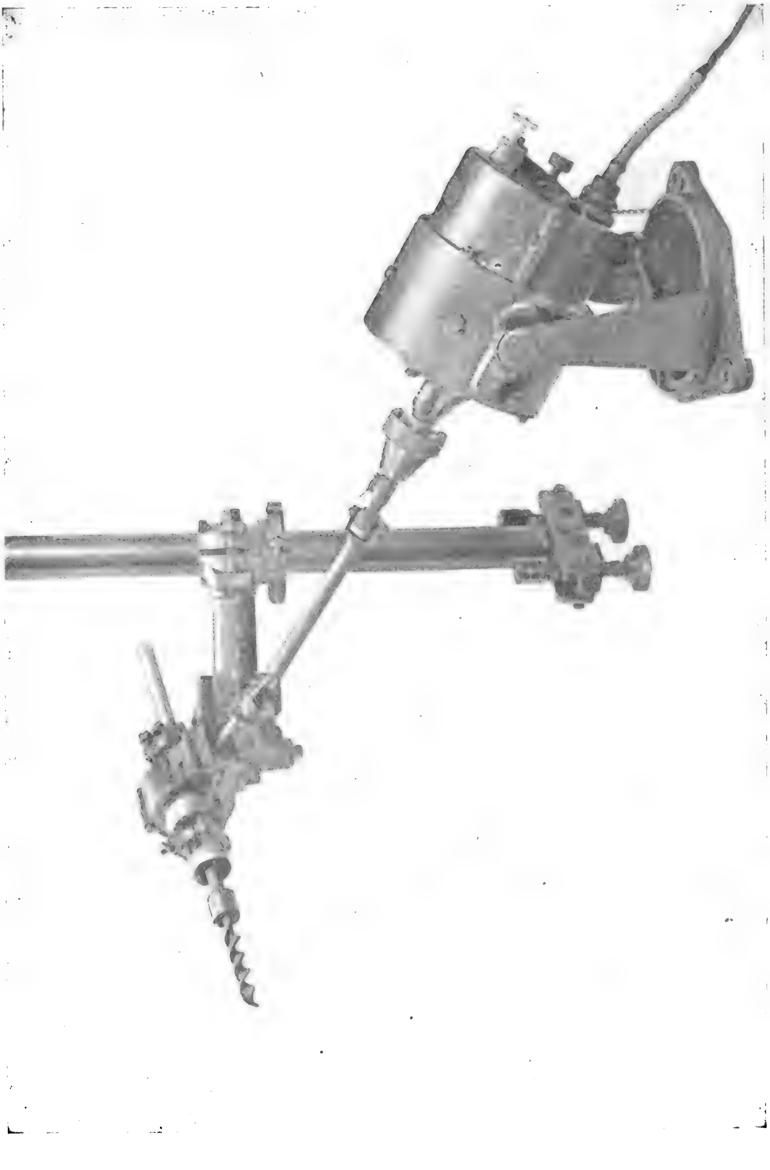

Fig. 136a.—Grant's Drill.

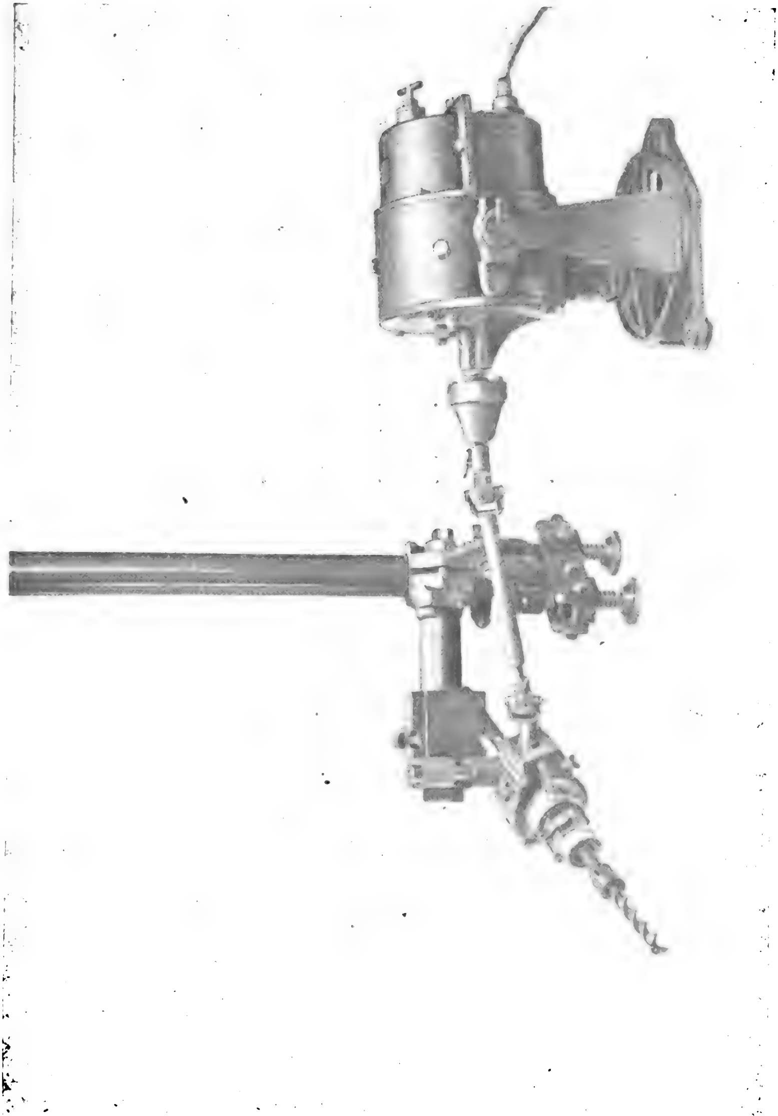

Fig. 136*b*.—Grant's Drill.

joint, and are fastened to the motor and the drilling machine respectively by means of an automatic coupling.

The motor is series wound, and is capable of giving 4 H.P. It is enclosed in a gas and water-proof casing, which is mounted on trunnions that are fixed to a revolving turn-table, which admits of it being tilted to any angle, or swung round to any desired position. The whole can be fixed to the base of an ordinary colliery tram.

The starting switch and resistance is also enclosed in the gas-proof case of the motor, connection being made by means of a detachable plug. The drill could, of course, be fitted equally well with an alternating current motor, if conditions rendered such a course desirable.

The weights of the various parts are as follows :—

Machine, ...	120 lbs.
Clip gear, ...	75 ,,
Column and arm, ...	280 ,,
Motor, ...	600 ,,
Shaft, ...	20 ,,

When at work the drill is operated by two men.

It has been used in Garswood Colliery and elsewhere for the purpose of driving stone drifts, and has proved very successful.

A larger machine, fitted upon a trolley, has been designed by Mr. Steavenson, and set to work in the Cleveland iron mines. It is made to work to about 6 H.P., and has done good service since its introduction.

Several attempts have been made to drive percussive drilling machines direct by electricity, a solenoid being employed; they have not, however, met with much success. A new drill of the percussive type, has, however, been brought out lately, that seems likely to be more successful. In this form the percussive action is produced by suitably-designed gear, the drill being driven from a rotating motor by means of a flexible shaft.

Where much percussive boring has to be done, the better plan is perhaps to fit up a small air-compressor near where drills are to work, this compressor being driven by an electric motor. The air thus compressed can be used for driving any of the well-known percussive drills, such as the Darlington or the Ingersoll. Where power has to be transmitted over a long distance, this course would be more economical than that of carrying the compressed air the whole way.

Winding.—The application of electric power in this direction has so far been limited. The chief difficulty to be encountered here is the large mass that must be set in motion and brought

to rest again within short spaces of time—conditions which exist at all large collieries—and the fact that the steam engine is applied directly to the work, and that, consequently, the gain if anything would not be great. While further applications of electricity for this purpose will doubtless be made from time to time, it is extremely questionable if the present methods will ever be entirely superseded by electrical appliances. Where electricity has been tried, it has, in most cases, been on a small scale only. At the Comstock Mines a fairly large plant is at work winding from a depth of 196 fathoms, the total load raised being about 34 cwts. The maximum speed is 600 feet per minute, and the load is raised in 2 minutes 10 seconds. In this instance it will be seen that the speed is very much below that required for most collieries, and unless a maximum speed about six times as great is adopted, and ample facilities provided for rapid starting and stopping, it cannot compete with the engines at present employed for such work about collieries, no matter how much lower the cost might prove.

At the Karwin Collieries in Silesia, electrical winding plants have been put down worked by polyphase motors. The largest of the two machines is one of 350 H.P. The winding shaft is 173 fathoms deep, and 4 tubs containing about 3 tons of coal are raised at each run. The winding drums are 11 feet 6 inches in diameter, and the speed of winding is about 885 feet per minute. The motor is worked by two separate levers, one for operating the starting resistance and the other for reversing. Powerful brakes are provided, which are operated by the attendant, but, in the event of the cage passing the landing place, current is switched off and the brake thrown on automatically. To prevent accident by possible stoppage of the current during the run, a small electro-magnet is placed in the circuit, which, if released, liberates a weight that at once puts on the brake.

Another winding-gear has lately been supplied by Messrs. Scott & Mountain to the Heckmondwike Collieries to wind from a staple about 50 fathoms deep. The motor is a four-pole one, working at about 50 H.P. and 600 revolutions per minute. An automatic brake is fitted, which sustains the load immediately the current is switched off, the coils of the electro-magnet being in circuit with the armature of the motor. The whole gearing is mounted upon a bed-plate made in sections to allow of its being sent down the pit. The motor is driven by a 50 kilowatt generator at the pit bank, which supplies current through 1030 yards of cable to the motor.

Signalling.—The application of electricity for this purpose has been adopted at nearly every mine of importance in which

mechanical haulage is used, as it is practically the only efficient method of transmitting signals from widely-separated points underground. It is also used for shaft work, although not to the same extent. The bells which are used for this purpose are of two types—tremblers and strikers. The tremblers ring continuously as long as the current passes, while the strikers give only a single stroke each time contact is made. When first used for mining work the tremblers were not satisfactory, and single-stroke bells became common, but tremblers have now been made to comply with the conditions required in the mine, and are again being put into use.

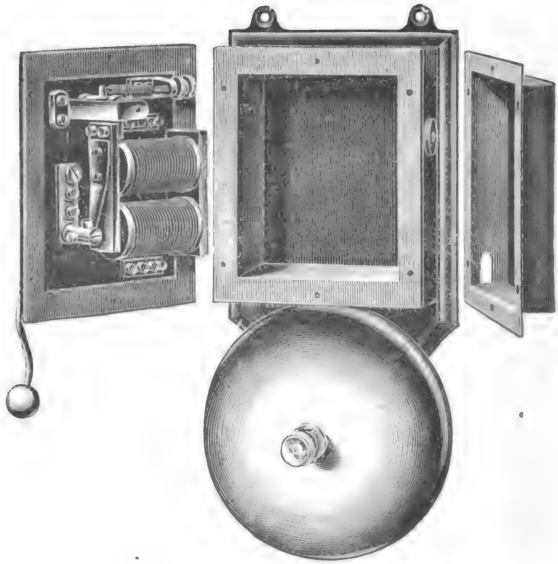

Fig. 137.—Enclosed Mining Bell.

Important features in the bells used for mining purposes are, that they should be enclosed in a water-tight case, and should be fitted with large electro-magnets, so as to provide ample power. It is not, as a rule, desirable to use bells with less than a 6-inch gong, and in many cases 8- or 9-inch gongs are used (Fig. 137).

The ringing-key is also another important part of the signalling installation, and should be of large size, ample strength, and similarly fitted in a water-tight box (Fig. 138). The bells are

worked by means of a battery, which is invariably of the Leclanche type, and each cell should be of large size, that known as the three-pint cell being quite suitable. The number of cells required will, of course, vary with circumstances, but it is always advisable to have a good many, as there is no more frequent source of trouble with mining bells than that of having

Fig. 138.—Ringing-key for Mining Work.

too few cells in the battery. The usual arrangement is to place the bell and battery in the engine-room, the battery being placed in a dry position, and, where the temperature is not too high (should the engine be a steam-engine), the bell can be placed as near the engineman as possible. The battery and bell are connected by an insulated copper wire, and the circuit completed by two naked galvanised iron wires, as shown in Fig. 139. The

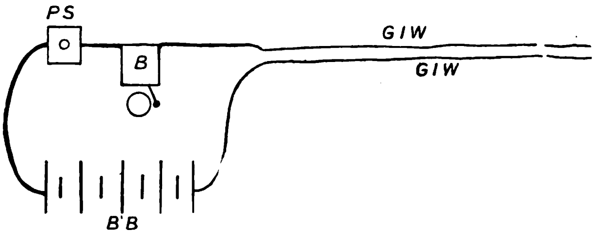

Fig. 139.—Diagram of Connections for Engine-plane Signal.

B = Bell. | B B = Battery.
P S = Plug switch. | G I W = Galvanised iron wire (bare).

iron wires are supported by insulators (Fig. 140), which are fastened to the timber by screws, the method of fixing being to place them from 6 to 8 inches apart, and fasten a wire to each.

Going round curves these insulators may be required every few feet, but on the straight road may have spans of from 10 to 15 yards. The bell can, of course, be rung from any point along the road by simply pressing the two wires together. This simple arrangement does very well for haulage signals, but could not be applied for shaft signals in many cases, and it is owing to the more complicated conditions, together with the greater facilities for mechanical signals, that electric bells are not at all common for shafts, as compared to haulage planes.

When employed for shaft work large heavy bells should be used, and a battery of sufficient size provided, as the work required from it is heavy. Bare wires are sometimes run in the shaft, but are seldom satisfactory, and one of the wires at least

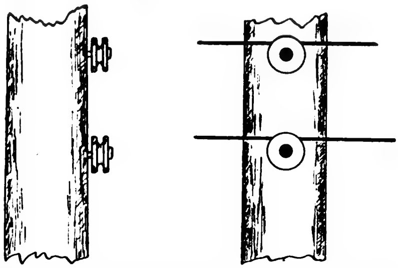

Fig. 140.—Insulators for carrying Bell Wire.

should be insulated. The best plan is to run a piece of wood casing down the side of the shaft, the casing should have a rather deep groove, into which the wire fits tightly, and after being gently forced into place the casing may be covered with a thin board, care being taken to keep all nails used well back from the wire. After fixing in position, the casing will be all the better if it receives a good coating of pitch, which will help to preserve it under the somewhat unfavourable conditions which exist in most shafts.

Telephones.—These instruments are now largely used about collieries, especially for surface work, although in a few cases they are used underground as well. One useful application is that of communicating between haulage planes and the engine-house by means of the signal wires. An instrument is fixed in the engine-house, and another, small enough to be conveniently carried in the pocket, is used by the persons who may have occasion to open communication with the engine-house from any part of the plane. When it is necessary to speak to the engine-house a pre-arranged signal is made in the usual

way, the engineman then moves a switch, which puts his telephone and its own battery into circuit. The small telephone carried by the person who wishes to speak to the engine-house is connected to the wires by two hooks, and conversation carried on in the usual way. A very neat and convenient form has lately been brought out by the General Electric Company, and consists of the usual telephone, with the addition of a small contact-box, which is fitted with two switches—one controlling the calling, the other the speaking (Fig. 141). Where such

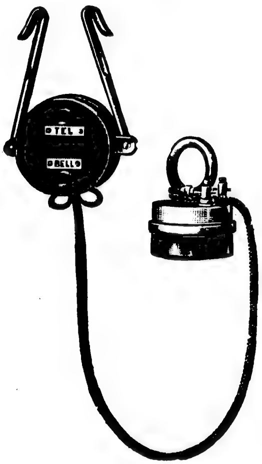

Fig. 141.—Watch Telephone.

instruments are used they must be kept clean, as dirt getting in around the diaphragm ruins their power of transmitting or receiving messages clearly. Telephones are also used in a good many collieries for establishing communication between the pit-bottom and the surface, and their use in this direction is likely to extend.

Ventilation.—In most mines driving of single headings, stone drifts, and such places, has to be carried out from time to time. When such places are driven some distance from the main air-ways, it becomes difficult to ventilate them properly, unless by special methods. The ventilation of such places is always an important matter, because they will usually give off considerable quantities of gas, and the method generally in use for such work is either to divide the road by a brattice, or to conduct air-pipes along one side. The necessity for partially obstructing

the air-current, so as to force it behind the brattice, or through air-pipes, is objectionable, as it interferes with the ventilation of the whole mine, and by far the better method is to place a small fan at the entrance to the heading or stone drift, and by this means to force the required air into the pipe, or behind the brattice, without interfering with the main current. This practice is one that is becoming very common in well-regulated collieries, and there is no better method of driving such a fan temporary than by electricity.

Small fans for such work may be of various types, but should be fast running, and will work best if coupled direct to the motor, as a great saving of space is effected by this means. A small blowing fan, driven by a belt, and suitable for the class of work referred to, is shown in Fig. 142.

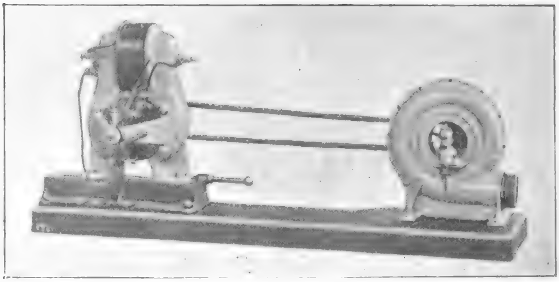

Fig. 142.—Small Fan for Ventilating Headings, &c.

There is, perhaps, no situation about a colliery that entails more danger from sparking, at either brushes or switches, than that occupied by a fan such as has been described. This is due to the fact that an advance driving always encounters a considerable quantity of fire-damp, should such be given off from the coal worked. The limited quantity of air, passed through a pipe or brattice, may return highly charged with gas (especially after a stoppage of the fan), and thus create dangerous conditions. It is, therefore, of great importance to see that the motor is completely enclosed, and that all switches are similarly protected. The utmost precaution must also be taken to have all cables and connections in good order, and free from any conditions likely to produce a spark.

Many examples of the use of electricity for driving fans are to be found on the Continent, some of which are on a somewhat large scale.

One example, at a Westphalian colliery, consists of a 40 H.P. motor which drives a Pelzer fan producing 50,000 cubic feet of air per minute, with a water-gauge of 3 inches. The motor is of the three-phase type, and is about half a mile distant from the generator.

The power required to drive fans will of course depend upon circumstances; but the work required is obtained by multiplying the number of cubic feet passing per minute by the pressure in lbs. per square foot; that is, the height of the water-guage in inches $\times$ 5·2; which gives the work done per minute in foot lbs. Allowance will have to be made for the efficiency of both the fan and motor in addition.

A fan produces 60,000 cubic feet of air per minute, with a water-gauge of 3 inches. Find the H.P. of driving motor if combined efficiency of fan and motor is 50 per cent.

$$\text{H.P. of motor} = \frac{3 \times 5{\cdot}2 \times 60{,}000 \times 100}{33{,}000 \times 50} = 56{\cdot}7.$$

Workshops, &c.—It is becoming a very common practice about collieries, where they do their own repairs, to drive the machine tools in the various shops by means of motors. This practice is now adopted by many large engineering firms, it having been sufficiently proved that economy is effected by such means. If economy results in engineering works it is likely to do so at collieries as well, and electrical methods offer special facilities in many classes of colliery work—*e.g.*, the building of a large cage, which may be best done outside. In such a case the greater part of the work consists in drilling holes, which can readily be done by means of an electrically-driven portable drill. There are many other examples of the same kind which might be quoted to show the general utility of electricity about collieries; but sufficient has been said to show that transmission of power by electricity about collieries has many important features in its favour, and, in popular parlance, has come to stay.

When we consider that it is only within the last twenty years that electric power has been introduced into collieries, we see that it has made very rapid strides indeed, and that it is destined to become even more important in the future, is shown by the eager way it has been taken up by colliery-owners and managers.

Whether present methods will continue to hold their ground or will be superseded by drastic changes, it is impossible to tell; but the mining engineer of the future must be prepared to regard electricity as one of the permanent forces with the applications of which he will be called upon to deal.

Accidents.—As already pointed out, if due precautions be taken in connection with the running of electric installations, accidents will but seldom occur. Persons who have occasion to work about electrical machinery should always bear in mind the nature of the current, and not allow their body to form part of a circuit where circuits of 400 volts or over are in operation. Nothing should be done about the wires unless rubber gloves be worn. Tools with insulated handles, or a piece of dry wood, could in many cases be used instead of the bare hand. A very good rule in handling live conductors or apparatus is to "keep one hand in your pocket." This ensures it not being used, and avoids the chance of making contact with both hands and getting the full current through the body. It is a noticeable fact that the majority of accidents occur with men of experience who have become careless by familiarity with dangerous currents.

Ambulance work is practised about most collieries; but the method of treatment for severe electrical shock may be here given with advantage. The method is that known as Sylvester's, and is as follows:—

Place the patient on the back on a flat surface, inclined a little upwards from the feet; raise and support the head and shoulders on a small firm cushion or folded article of dress placed under the shoulder-blades. Draw forward the patient's tongue and keep it projecting beyond the lips—an elastic band or piece of string over the tongue and round the chin will hold it in this position. Remove all tight clothing from about the neck and chest, especially the braces.

To Imitate the Movements of Breathing.—Standing at the patient's head, grasp the arms just above the elbows and draw them gently and steadily upwards above the head, and keep them stretched upwards for two seconds. (By this means air is drawn into the lungs.) Then turn down the patient's arms and press them gently and firmly against the sides of the chest. (By this means air is pressed out of the lungs.)

Repeat these movements alternately and deliberately about fifteen times a minute until spontaneous efforts to respire are perceived, upon which immediately cease to imitate the movements of breathing and proceed to induce circulation and warmth.

To Promote the Circulation.—Rub the limbs upwards with a firm, grasping pressure, employing handkerchiefs, flannels, &c.

Promote the warmth of the body by the application of hot flannels, bottles, or bricks to the pit of the stomach, armpits, between the thighs, and to the soles of the feet.

Allow the air to play freely about the patient—*i.e.*, avoid

crowding around him. On the restoration of animation a teaspoonful of warm water should be given, and when the power of swallowing has returned, small quantities of wine, warm brandy and water, or coffee should be administered. Put the patient to bed and encourage sleep.

If necessary the treatment should be persevered in for some hours, cases being on record of resuscitation taking place after three hours' treatment.

Cautions.—Do not allow crowding round the patient; avoid rough usage; keep the tongue secured well forward; under no circumstances hold the person up by the feet; and do not place the patient in a warm bath, except by a doctor's order, and then only as a momentary excitant.

Another method that has been applied by some French physicians is that of passing oxygen gas into the lungs, a suitable mouthpiece being held over the patient's mouth while this is being done. The action of the oxygen is to restore the blood to its normal condition, and thereby help resuscitation.

The appearances which usually accompany death are:—Breathing and the heart's action cease entirely; the eyelids are generally half closed, the pupils dilated; the tongue approaches the upper edges of the lips, and these, as well as the nostrils, are covered with a frothy mucus; and coldness and pallor of surface increase.

THE END.

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